ISIS

INDIVIDUALIZED SCIENCE INSTRUCTIONAL SYSTEM

FIRE!

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INDIVIDUALIZED SCIENCE INSTRUCTIONAL SYSTEM

FIRE!

ANNOTATED TEACHER'S EDITION

Ginn and Company

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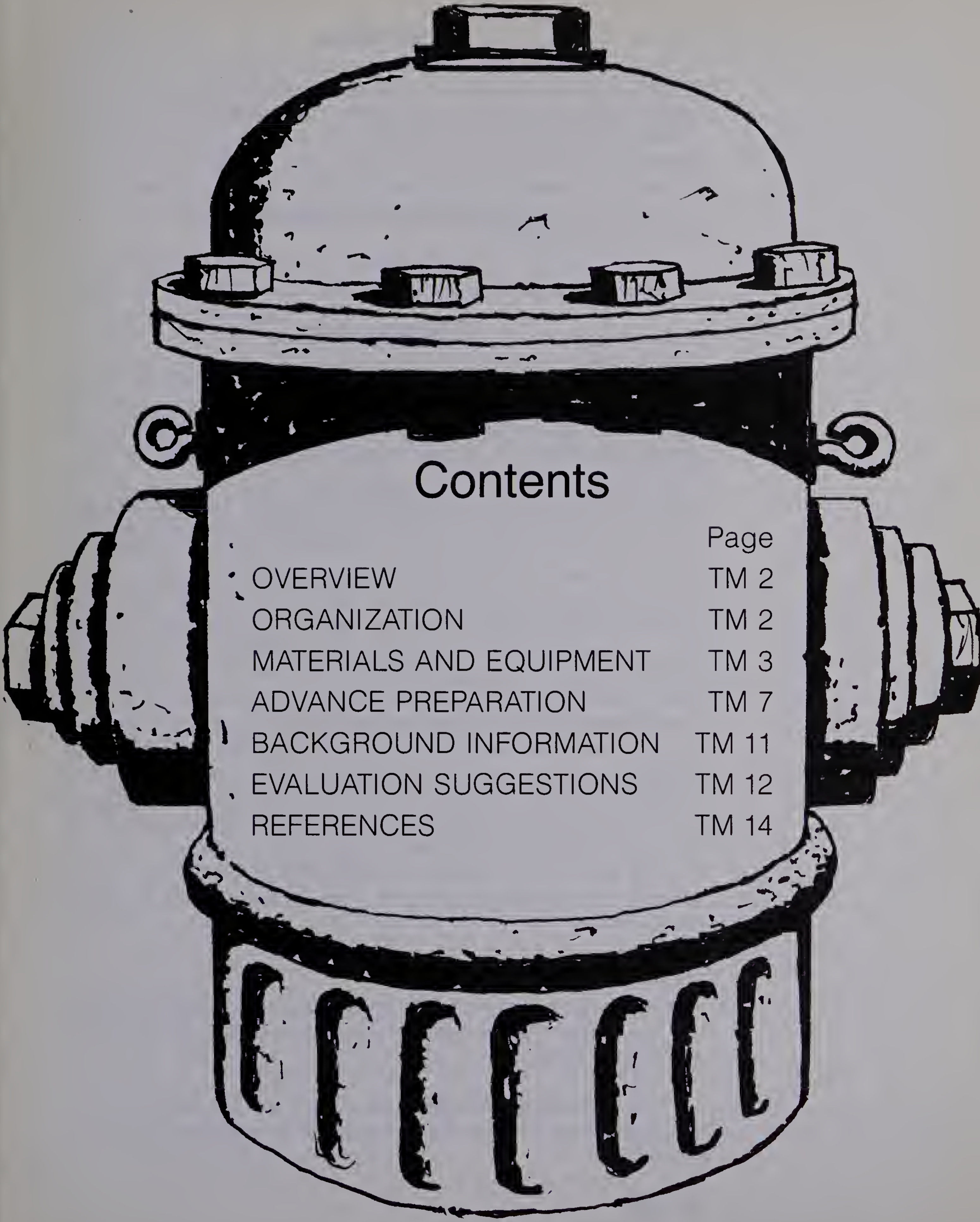

Contents

Overview

In *Fire!,* students explore the burning process. They investigate the conditions required for a fire. The removal of one or more of these conditions is the focus of activities on fire prevention and control. Students learn ways in which fire causes injury and death, and how to reduce the chance of injury and death in a fire. Students also learn what conditions are necessary for an explosion and the precautions to take for avoiding explosions.

Organization

This minicourse contains ten core activities, four advanced activities, and three excursion activities. The first activity in each section is a planning activity. It should be done before any of the other activities in that section. Activity 10 is a required activity. Activities 2 through 10 may be done in any order.

In some core activities, students learn about a past and present theory of burning. They study what happens to the atoms of substances when the substances burn or explode. They learn what conditions are necessary to cause a fire and an explosion, and how to put out a fire by removing one or more of those conditions. In other core activities, students learn to classify materials as combustible, flammable, and noncombustible. They learn about safe and unsafe procedures for storing and using materials that will burn or explode. And they study the ways that fire can be the direct or indirect cause of injury or death, and how to reduce the chances of injury and death in a fire.

In the advanced activities, burning is described as a chemical oxidation-reduction reaction. Students study what happens to the products of burning when the amount of fuel and oxygen is varied. And activation energy is described: how it is related to the energy changes in a burning reaction, and how it is affected by a catalyst.

In the excursion activities, students learn how to make flammable materials less flammable, and why, under certain conditions, paper doesn't ignite.

Duplicating Masters

The *Hazard Checklist* is an integral part of Core Activity 9. Students use the checklist when inspecting their homes for potential fire or explosion hazards.

The *Burning Experiment Form* is an integral part of Advanced Activity 13. Students use the form as a guide in designing their own experiments.

Fabric Set

The Fabric Set, supplied separately, is used with Excursion Activity 16. Students treat some of the fabrics in the set to make them fire resistant. Then they test the treated and untreated fabrics to see how flammable they are.

Materials and Equipment

The following table shows the quantity and the frequency of use of each item used in each activity. The activities that require no materials are not listed in the table.

It is important to collect and organize all the materials for each minicourse before the students begin any of the activities, since the students will be working simultaneously on different activities. Having all materials readily available allows students to do the activities in the order they choose. The amount of material you will need to make available will depend on the number of lab groups that will be doing each activity. As lab groups use the "skipping option," and as they scatter themselves throughout the activities, the total amount of materials needed at one time for each activity will decrease.

CONSUMABLE ITEMS	**MINIMUM MATERIALS PER LAB GROUP PER ACTIVITY***												
	Act. 1	Act. 2	Act. 3	Act. 4	Act. 5	Act. 6	Act. 8	Act. 9	Act. 10	Act. 13	Act. 14	Act. 16	Act. 17
Bag, plastic or small paper							2						
Baking soda, 1 g						1							
Borax, 1 tsp												1	
Boric acid, 1 tsp												1	
†*Burning Experiment Form*										1			
†Burning Set			1										
Candle, birthday, approx. 5 cm long		1				2							
Cardboard, 3 cm x 6 cm				2									

*A lab group is defined as one student, a pair of students, or any size group of students that you choose.
†See Advance Preparation.

Materials and Equipment (Continued)

CONSUMABLE ITEMS	MINIMUM MATERIALS PER LAB GROUP PER ACTIVITY*												
	Act. 1	Act. 2	Act. 3	Act. 4	Act. 5	Act. 6	Act. 8	Act. 9	Act. 10	Act. 13	Act. 14	Act. 16	Act. 17
Charcoal, small piece, or steel wool				1									
Cloth, cotton, 3 cm x 6 cm				2									
†Fabric Set												1	
Grease pencil for labeling						1							
† *Hazard Checklist*								1					
†Hydrogen peroxide, 3% solution, 200 ml				1									
Index card (4″ × 8″)									2-5				
†Lycopodium powder or flour, 2 tsp							1						
†Limewater, 15-20 ml										1			
Manganese dioxide, MnO_2, powder, 1 g				1									
Matches, safety, friction		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
Paper, notebook, 20 cm x 20 cm													1
Paper, 3 cm x 6 cm				2									
†‡ Safety contract, signed	✓												
Steel wool, very fine and loosely packed, 1-cm ball		1											
Sterno jelly											1		
Straw, soda (small bore)				1			1						
Sugar cube											2		
Tobacco ash, cigarette											1		

*A lab group is defined as one student, a pair of students, or any size group of students that you choose.
†See Advance Preparation.
‡See Background Information.

Materials and Equipment (Continued)

CONSUMABLE ITEMS	MINIMUM MATERIALS PER LAB GROUP PER ACTIVITY*												
	Act. 1	Act. 2	Act. 3	Act. 4	Act. 5	Act. 6	Act. 8	Act. 9	Act. 10	Act. 13	Act. 14	Act. 16	Act. 17
Towel, paper			1				1			1		2-3	
Vinegar-water (½ vinegar, ½ water), 50 ml						2							

NONCONSUMABLE ITEMS	MINIMUM MATERIALS PER LAB GROUP PER ACTIVITY*											
	Act. 1	Act. 2	Act. 3	Act. 4	Act. 5	Act. 6	Act. 8	Act. 12	Act. 13	Act. 14	Act. 16	Act. 17
Asbestos glove or pot holder												1
Asbestos pad or mat, or metal lid		1	1				1				1	
Asbestos pad or mat, about 30 cm x 20 cm				1								
Balance, laboratory		1										
Beaker, 250-ml		1				2			1			
Beaker, 600-ml											1	
†Bunsen burner			1	1			1		1	1	1	1
†Clamp, burette (metal sleeve only)				2								
Graduated cylinder, 100-ml						1			1		1	
Holder, test-tube									1	1		
Jar, baby-food with lid				1								
Lid, from baby-food jar						2				2		

*A lab group is defined as one student, a pair of students, or any size group of students that you choose.
†See Advance Preparation.

Materials and Equipment (Continued)

NONCONSUMABLE ITEMS	MINIMUM MATERIALS PER LAB GROUP PER ACTIVITY*											
	Act. 1	Act. 2	Act. 3	Act. 4	Act. 5	Act. 6	Act. 8	Act. 12	Act. 13	Act. 14	Act. 16	Act. 17
Nail, about ten-penny size							1					
†Pan, aluminum foil, pie				1								
Safety goggles		1	1	1	1	1	1		1	1	1	1
Stapler												1
Support ring										1	1	1
Support stand				2						1	1	1
Teaspoon			1			1	1			1	1	
Test tube, 18 mm x 150 mm, with #2 stopper									1			
Thermometer, Celsius, −10°C to 110°C												1
Timer or watch with second hand				1								
Tongs, or tweezers			1	1	1						1	1
Wire gauze											1	
Wire gauze (without asbestos center)										1		1
Minicourse *Actions and Reactions*								✓				
Resource Unit 1				✓								
Resource Unit 10		✓										
Resource Unit 15						✓			✓			
Resource Unit 17			✓	✓			✓					
Resource Unit 22					✓							

*A lab group is defined as one student, a pair of students, or any size group of students that you choose.
†See Advance Preparation.

Advance Preparation

Do not make substitutions for chemicals called for in the minicourse. A substitution could be very dangerous for both teachers and students.

Students should be cautioned to observe safety rules, but should not be restrained from doing any of the suggested activities.

Activity 1 Core Page 2

A sample safety contract may be found in *Managing ISIS*. Be sure to make enough copies–one for each student doing the minicourse. The students must read, sign, and give you their contracts before leaving the planning activity.

Activity 3 Core Page 12

Each lab group needs a Burning Set that consists of the materials listed below. You may want to keep a supply of each item in separate labeled containers.

- steel nail
- newspaper, 4 cm x 4 cm
- plastic, 1 cm x 4 cm
- block of wood, 2 cm x 2 cm x 2 cm
- leather, 1 cm x 4 cm
- table salt, 2 tsp
- table sugar, 2 tsp
- Styrofoam cup
- carpeting, 4 cm x 4 cm
- cloth, cotton, 1 cm x 4 cm
- drapery fabric, 1 cm x 4 cm
- chalk, 2 cm in length

Note: Current research on the toxic effects of products of burning is incomplete. It has long been known that toxic gases such as CO, SO_2, HCl, and NH_3 are given off when many common materials (wood, plastic, fabrics, etc.) burn. How much toxic gas, under what conditions, and with what tolerance level is not known. During burning, many materials made from polyvinyl chloride produce poisonous gases (especially hydrogen chloride and vinyl chloride monomer). So polyvinyl-chloride materials (such as shower curtains and floor mats) should not be used as samples in the Burning Set.

It has been established that a very different set or concentration of products may result from the burning of a small fabric sample as opposed to a large sample (e.g., a shirt versus a closetful of clothes). Small samples burned in a well-ventilated room do not usually cause problems.

After you have gathered samples for the Burning Set, test the materials before students use them. Some samples may not react the way you might expect them to. For example, some samples of drapery fabric may be *both* combustible and flammable while other samples may be *just* combustible.

Activity 4 Core Page 16

Each lab group needs these materials: 2 pieces of paper (the thickness of notebook paper), 3 cm x 6 cm; 2 pieces of cardboard (at least 0.5 cm thick), 3 cm x 6 cm; 2 pieces of cotton cloth, 3 cm x 6 cm.

The burette clamps must have metal sleeves. Rubber or plastic sleeves will scorch or burn if used in this activity.

A 3% hydrogen peroxide, H_2O_2, solution is needed for this activity. The commonly used antiseptic hydrogen peroxide can be used here—it's a 3% solution. A 30% hydrogen peroxide solution, available in some labs, can be used if it is diluted to a 3% solution. To dilute a 30% solution, start with 12 ml of the 30% solution and add 100 ml of water. Students should never use a solution that's more than 3% H_2O_2—it can produce dangerous explosions in closed containers.

Manganese dioxide, MnO_2, is the preferred catalyst for this oxygen-generation reaction. Activated charcoal could be substituted to eliminate any question about the source of the oxygen gas.

A shallow pan is needed for the H_2O_2 decomposition reaction with MnO_2. A foil pie or cake pan works well. The decomposition reaction may take about twenty minutes. Caution students to provide enough time for the reaction to be completed.

If you want to try a different method of producing oxygen, avoid using $KClO_3$ and MnO_2–they're too explosive! The use of an oxygen generator is all right as long as students are directed to evacuate the air from the generator for a minute or so before collecting oxygen gas by water displacement. Hydrogen peroxide is preferred in any setup you choose. It's the safest source of oxygen gas.

Activity 6 Core Page 26

Candles the size of birthday candles are called for in this activity. Larger candles will not be an effective replacement here.

You may want to dispense the baking soda in separate containers. If so, fill each container, label it *baking soda,* cap and store it.

Preparation of vinegar-water: Fill a bottle 1/2 full of distilled vinegar. Add tap water to fill the bottle. Cap the bottle, label it *vinegar-water,* and store it until needed.

Activity 8 Core Page 37

Caution: Other explosion demonstrations that are described in various source books and lab manuals are not advised. These are potentially dangerous, especially if done by the students. To avoid any possible legal consequences, don't demonstrate those explosions and don't allow students to perform those explosions.

Caution: The lycopodium powder will burn rapidly when ignited in air. Be sure students are well away (1 or more metres) from the fire when other students are doing this experiment. Fine flour or fine corn starch,

can be substituted for lycopodium powder, but they don't show the same dramatic results as the lycopodium powder.

You may want to provide a bottle labeled *Used Lycopodium Powder*. Then the excess powder, not used by students, can be saved for later.

The burette clamps must have metal sleeves. Rubber or plastic sleeves will scorch or burn if used in this activity.

Activity 9 Core Page 44

The *Hazard Checklist*, supplied separately, is needed for this activity. Be sure to make enough copies–one for each student doing the minicourse.

Activity 13 Advanced Page 53

Preparation of limewater: Limewater can be prepared by adding an excess of calcium hydroxide, $Ca(OH)_2$, or calcium oxide, CaO, to distilled water. Stopper the bottle, shake well, and let it stand for 24 hours. Pour off the clear limewater and keep it in a stoppered bottle.

Note: You may need to filter the limewater if it isn't clear after 24 hours. As students pour from the bottle, the solution will become cloudy over a period of time and should be replaced. (Repeated exposure to the CO_2 in the air will eventually make the limewater turn cloudy in the dispensing bottle.)

The *Burning Experiment Form,* supplied separately, is needed for this activity. Be sure to make enough copies–one for each student doing the minicourse.

Activity 14 Advanced Page 59

Tobacco ash can be obtained from ashtrays in areas where smoking occurs. Collect the ash in small jars and label the jars *Tobacco Ash*.

Activity 16 Excursion Page 69

The Fabric Set, supplied separately, is needed for this activity. The set consists of these following six types of fabrics: cotton, nylon, acrylic, polyester, rayon, acetate.

Cut each piece of fabric into squares, each about 5 cm x 5 cm. With indelible ink, label each square accordingly (e.g., cotton, nylon, acrylic, etc.). Then place the squares of each type of fabric into a container (paper cup, jar, box, etc.). Label the container with the name of the fabric that is inside. You may want to place the six containers in a large box.

Note: If substitutes are used for any of the fabrics needed for this activity, use the table in Figure 1 as a reference. Try to select a good variety of materials.

FLAMMABILITY OF SELECTED FIBERS AND FABRICS

FLAMMABLE	FLAME RESISTANT	NONCOMBUSTIBLE
*cotton *linen *acetate *triacetate acrylic *rayon	**silk wool modacrylic ***nylon ***olefin ***polyester ***spandex ***rubber ***anidex	***saran glass

*Flame retardant, treatable
**Flammable in certain forms (e.g., colored)
***Ignites at a high temperature

Figure 1

Listed below are selected common trademarks for the fabrics listed in Figure 1. The selected trademarks are from *Fibers and Fabrics,* by Josephine M. Bladford and Lois M. Gurel (1970 U.S. Government Printing Office, U.S. Department of Commerce, November).

acrylic: Acrilan Creslan, Orlon, Zefran
acetate: Celera, Celaperm, Acele
triacetate: Arnel
rayon: Avril, Avron, Jetspun, Zantrel
modacrylic: Dynel, Verel
nylon: Antron, Cantrece, Caprolan
olefin: DLP, Vectra, Herculon
polyester: Dacron, Fortrel, Vycron, Trevira, Kodel
spandex: Spandelle, Lycra
rubber: Lastex, Lactron
glass: Fiberglass

Activity 17 Excursion Page 73

This activity is most successful when the paper pot is made with paper that is thin but able to hold water. Duplicating paper, notebook paper, and glossy magazine paper work well. (Avoid using newspaper; it doesn't work well at all.) Test the paper beforehand to prevent the frustrating experiences of using pots that burn or leak.

The wire gauze provided must be larger than the base of the pot. Most student-made pots will have bottoms about 10 cm x 10 cm square. Be sure that the wire gauze is larger than 10 cm x 10 cm so that the pots will fit.

Alcohol burners are not adequate for use here. Their heat production is too inefficient. Use a Bunsen burner or a commercial propane torch (burner) for this activity. The water must boil for the activity to be fully effective.

Background Information

Safety Contracts

It is recommended that all students sign a safety contract early in the school year before beginning any minicourse. The safety contract should mention the following considerations:

Wearing safety goggles when doing or watching investigations that call for safety goggles in the equipment list
Mixing chemicals only as directed
Using no more chemical reagents than called for
Disposing of wastes only as directed (by teacher)
Thorough washing with water in case of spills and cleaning up the spilled areas
Reporting all accidents, no matter how minor they may seem
Knowing the location of fire safety equipment
Statement of awareness of the above matters and each student's signature on individual copies of the safety contract.

A sample safety contract can be found in *Managing ISIS*.

To help enforce the provisions of the safety contract, various cautionary notes appear in the student's book. You will note that these cautions emphasize eye safety in particular.

Eye Safety

It is recommended that students wear safety goggles whenever they are working in a laboratory situation. Although a particular student may not be working with hazardous materials, other students nearby may be.

Working with Chemicals

Early in the school year, spend some time instructing your students on general laboratory safety and on appropriate precautions for working safely with chemicals. There are several general safety suggestions in *Managing ISIS*.

Disposal and Conservation of Materials

You will have to direct students on methods for safely conserving and disposing of various liquids and solids. Refer to *Managing ISIS* for general suggestions. Specific suggestions for this minicourse follow on page 12.

Special Safety Notes

As students begin the minicourse, review with them the location and operation of fire-safety devices in the classroom – fire extinguishers (common materials and commercial extinguishers), fire blankets, and fire showers. This might be a good opportunity to review fire-safety procedures with the entire class.

Prepare special metal disposal containers with clearly labeled lids for flammable and combustible materials.

Provide adequate ventilation for the burning tests in Activities 3, 4, 8, and 16. This can involve the entire classroom or a specific work area where students can do the tests.

Depending upon classroom arrangement, it may be desirable to have *all* combustion tests performed in a designated work area. Then safe conditions can be insured, including adequate ventilation for noxious gases, absence of paper and books, absence of other students, and availability of fire-safety equipment. Combustion tests are done in Activities 2, 3, 4, 5, 6, 8, 13, 14, 16, and 17.

Remind students to clear their work areas of papers and books when they are testing combustibles. For the materials-testing activities, ask students to have a beaker of water handy as a fire-safety device.

The use of Bunsen burners is highly recommended for the activities in this minicourse. Alcohol burners are potentially dangerous and fail to provide the heat needed in many of the included activities. If alcohol burners must be used, be sure to caution students about the dangers related to their use (spilling, evaporation, glass breakage, explosiveness, etc.). An alcohol burner *must not* be used in Activities 3 and 8 where the burner is tipped.

Because of the increased hazard potential of this minicourse, students are directed to sign a safety contract. Be sure all students do so by the time they complete *Activity 1: Core Planning*. (See Advanced Preparation for Activity 1.)

Evaluation Suggestions

In addition to the Minicourse Test, you might use some or all of the following suggestions to evaluate your students.

On the Minicourse Test, no test items have been provided for Objective 13-2 because of the nature of the objective. It is suggested that the evaluation of the objective take place as students work through Activity 13. The *Burning Experiment Form* could be used as the criterion. Or, as a performance evaluation after the minicourse is completed, students could be required to design and carry out an experiment. Another possibility is to ask an essay question requiring students to describe the design and procedure for carrying out an experiment.

Essay Questions

Four essay questions and their model answers follow. The first three questions are related to core activities, and the last question is related to an excursion activity.

1. What are four ways in which fire can cause death? Which is the most frequent way? Which is the least frequent way? Also describe *how* each way causes death.

Answer: Fire can cause death by (1) suffocation from lack of oxygen; (2) smoke and poisonous gases from burning; (3) flames; (4) high temperature. The most frequent cause of death is asphyxiation (1 and 2). The least frequent cause of death is burns (3 and 4).

Suffocation occurs when the supply of oxygen is decreased. A person becomes confused and finds it difficult to think clearly. Then body coordination is lessened, fatigue is rapid, and breathing stops. *Smoke and poisonous gases* cause suffocation and lung damage. *Flames* can cause death through burns. Most people do not survive when they have burns on 50% or more of their bodies. *High temperature* can cause death when hot smoke (over 150°C) is taken into the lungs. It burns the lung tissues causing death by suffocation.

2. Why should you know more about a common household material than just whether or not it will burn?

Answer: It is almost impossible to remove all combustible materials from the home. But you can minimize the use of flammable materials and take special precautions in using and storing them.

3. Explain the advantage of making fabrics flame retardant. Discuss the problem that can arise when certain flame-retardant items melt.

Answer: Flame-retardant fabrics burn slowly. If flame-retardant clothing catches on fire, the flames spread more slowly, making them easier to extinguish. Often they will extinguish themselves. In the process of slowing down the burning rate, however, melting can occur, producing toxic gases and skin burns.

4. Many people have died when they have gone into a burning house to attempt to rescue someone trapped inside. What are the fire hazards that these rescuers usually tend to ignore?

Answer: The rescuers are usually concerned only with the presence of flames. Once inside, however, they can be overcome easily by smoke, toxic gases, or heat.

Performance Items

The following items require individual students to demonstrate a skill.

1. Given four samples of materials, determine which has the highest ignition point and which has the lowest ignition point.

2. Given four fabric samples, determine which would be the least hazardous fabric to wear if a flame came in contact with it. Determine which would be the most hazardous to wear.

References

Bladford, Josephine M., and Gurel, Lois M. November 1970. *Fibers and fabrics*. Washington, D.C.: U.S. Government Printing Office, U.S. Department of Commerce.
This is a good source for information on the care and uses of natural and synthetic fibers.

Consumer Product Safety Commission. *Hazards of flammable liquids*. Washington, D.C.: Consumer Product Safety Commission.
This information sheet provides a brief discussion of fire problems and a list of safety procedures.

Emmons, Howard W. July 1974. Fire and fire protection. *Scientific American,* pp. 21-27.
This article presents a comprehensive, highly technical examination of the mechanism of fire.

Mosbacher, C. J., ed. October 1976. Fire—can you put it out? *Research/Development,* pp. 18-21.
This article describes the use of halogenated compounds in fire fighting.

National Commission on Fire Prevention Control. 1973. *American burning*. Washington, D.C.: U.S. Government Printing Office (73-600022).
This is an examination of the fire problem in the United States.

National Fire Protection Association. 1969. *Fire protection handbook*. 13th ed. Boston: National Fire Protection Association.
This is a quick-reference pamphlet on fire protection.

National Safety Council. *Flammable liquids in the home*. rev. ed. Chicago: National Safety Council.
This is a useful Safety Education Data Sheet.

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Home Office: Lexington, Massachusetts 02173
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foreword

Evidence has been mounting that something is missing from secondary science teaching. More and more, students are rejecting science courses and turning to subjects that they consider to be more practical or significant. Numerous high school science teachers have concluded that what they are now teaching is appropriate for only a limited number of their students.

As their concern has mounted, many science teachers have tried to find instructional materials that encompass more appropriate content and that allow them to work individually with students who have different needs and talents. For the most part, this search has been frustrating because presently such materials are difficult, if not impossible, to find.

The Individualized Science Instructional System (ISIS) project was organized to produce an alternative for those teachers who are dissatisfied with current secondary science textbooks. Consequently, the content of the ISIS materials is unconventional as is the ividualized teaching method that is built into them. In contrast with many current science texts which aim to "cover science," ISIS has tried to be selective and to limit our coverage to the topics that we judge will be most useful to today's students.

Obviously the needs and problems of individual schools and students vary widely. To accommodate the differences, ISIS decided against producing tightly structured, pre-sequenced textbooks. Instead, we are generating short, self-contained modules that cover a wide range of topics. The modules can be clustered into many types of courses, and we hope that teachers and administrators will utilize this flexibility to tailor-make curricula that are responsive to local needs and conditions.

ISIS is a cooperative effort involving many individuals and agencies. More than 75 scientists and educators have helped to generate the materials, and hundreds of teachers and thousands of students have been involved in the project's nationwide testing program. All of the ISIS endeavors have been supported by generous grants from the National Science Foundation. We hope that ISIS users will conclude that these large investments of time, money, and effort have been worthwhile.

Ernest Burkman
ISIS Project   Tallahassee, Florida

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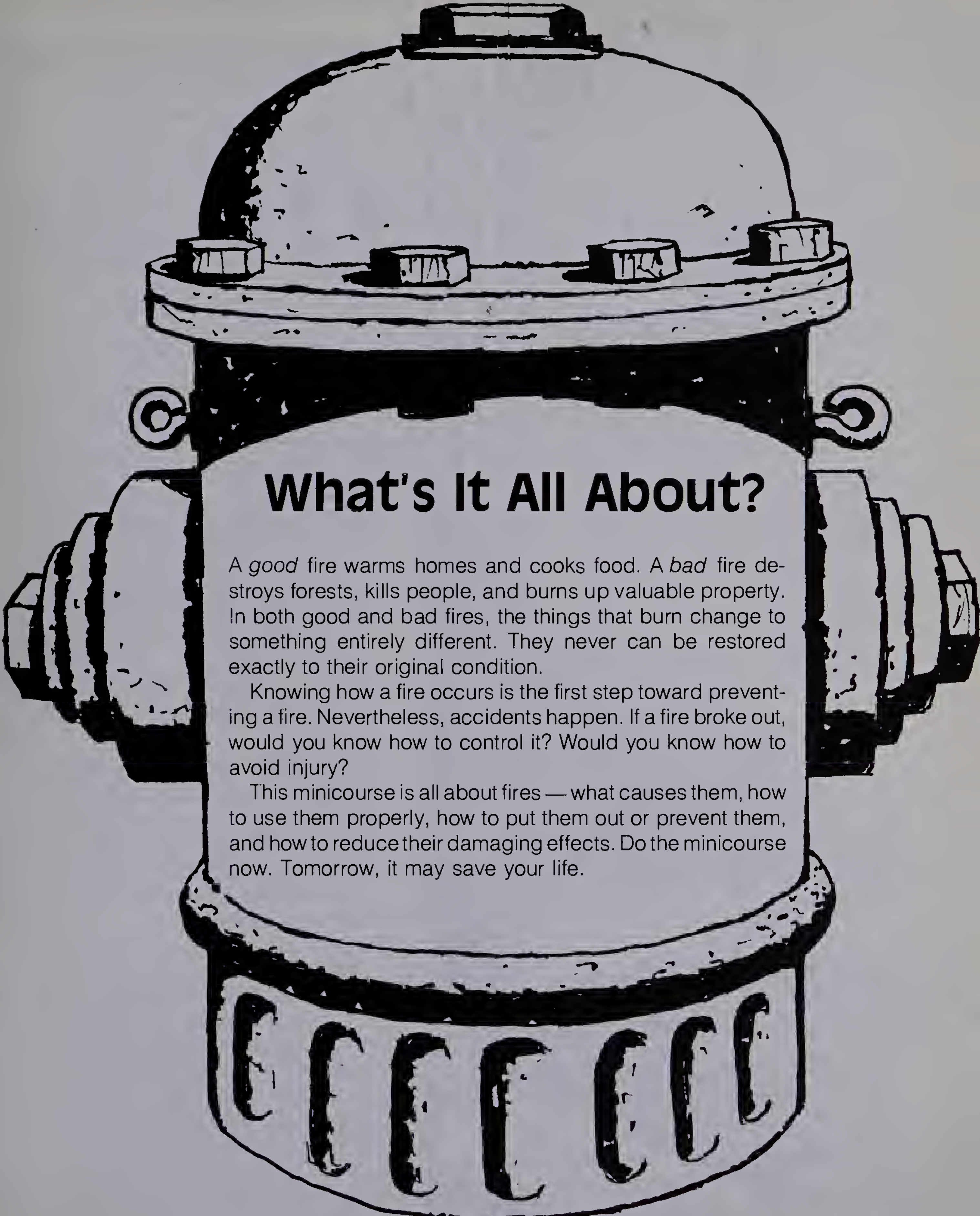


What's It All About?

A *good* fire warms homes and cooks food. A *bad* fire destroys forests, kills people, and burns up valuable property. In both good and bad fires, the things that burn change to something entirely different. They never can be restored exactly to their original condition.

Knowing how a fire occurs is the first step toward preventing a fire. Nevertheless, accidents happen. If a fire broke out, would you know how to control it? Would you know how to avoid injury?

This minicourse is all about fires — what causes them, how to use them properly, how to put them out or prevent them, and how to reduce their damaging effects. Do the minicourse now. Tomorrow, it may save your life.

See Materials and Equipment, p. TM 4. See also Advance Preparation, p. TM 7.

Activity 1
Core Planning

If you have not already signed a safety contract, do so now. There should be a copy somewhere in the classroom. If not, ask your teacher for one. Read the contract carefully. Sign it after you fully understand each item. Then give the signed safety contract to your teacher and continue with this planning activity.

Any activities you need to do may be done in any order. Notice that Activity 10 is a required activity. Be sure you do it.

Activity 2 Page 6

Objective 2-1: Describe the results of Lavoisier's experiments on burning and their effect on the acceptance of the phlogiston theory of burning.

Sample Question: What was shown by Lavoisier's experiments?

a. Substances lose weight when they burn.
b. Substances containing phlogiston will not burn.
c. Substances combine with oxygen when they burn.
d. Phlogiston has no weight.

Objective 2-2: Explain how the law of conservation of mass applies to burning.

Sample Question: How is mass conserved in a burning reaction?

a. All substances in the burning reaction gain weight.
b. All substances in the burning reaction lose weight.
c. The mass of the substances produced by burning is equal to the mass of the substances before burning.
d. The mass of the substances produced by burning is less than the mass of the substances before burning.

Activity 3 Page 12

Objective 3-1: Describe what is meant by combustible, noncombustible, and flammable and recognize examples of each.

Sample Question: Match each substance with its burning characteristic.

Substance
a. kerosene
b. concrete block
c. fire-resistant fabric

Characteristic
1. combustible but not flammable
2. flammable
3. noncombustible

Activity 4 Page 16

Objective 4-1: Describe the three conditions that must be present for a fire to occur.

Sample Question: What three things must exist at the same time to produce a fire?

Activity 5 Page 23

Objective 5-1: Describe what burning is in terms of atoms and how the atoms are affected during burning.

Sample Question: What happens to the atoms of a substance when it burns?

a. Oxygen atoms are released from the burning substance, thus producing oxygen gas.
b. Oxygen atoms from the air combine with atoms in the burning substance.
c. Atoms within the burning substance combine with each other.
d. Oxygen atoms in the substance are destroyed by the heat of the fire.

Activity 6 Page 26

Objective 6-1: Describe three general ways to control or put out a fire, and identify an example of each way.

Sample Question: What must you remove to put out a fire?

a. the oxygen
b. the fuel
c. enough heat so the temperature of the fuel falls below its ignition point
d. either a, b, or c

Objective 6-2: Identify the proper kind of fire extinguisher for putting out different kinds of fires.

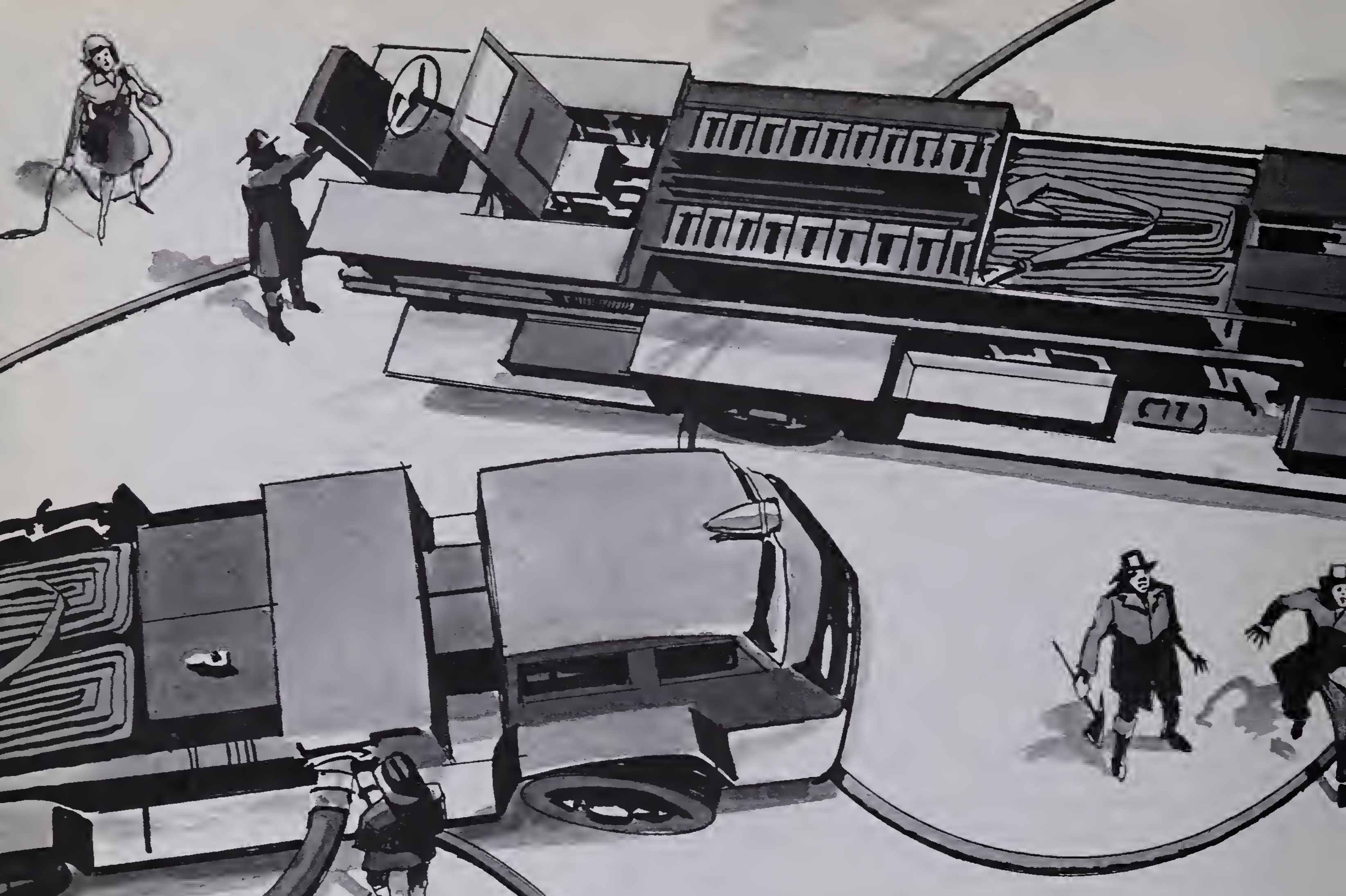
Sample Question: Match the kind of fire with the type of fire extinguisher that should be used to put out the fire.

Fire Extinguisher
a. water
b. dry chemical
c. foam

Kind of Fire
1. burning wood, paper, or cloth
2. burning gasoline
3. electrical fire
4. burning grease

Answers

2-1. c **2-2.** c **3-1.** a-2, b-3, c-1
4-1. oxygen, fuel, temperature high enough to ignite fuel **5-1.** b **6-1.** d
6-2. a-1; b-2, 3, 4; c-2, 4



Activity 7 Page 32

Objective 7-1: Describe ways that fire can be the direct or indirect cause of injury or death, and tell how to reduce the chance of injury and death in a fire.

Sample Question: Each of the following can result from fire. Which one(s) should be regarded as a direct result of a fire?

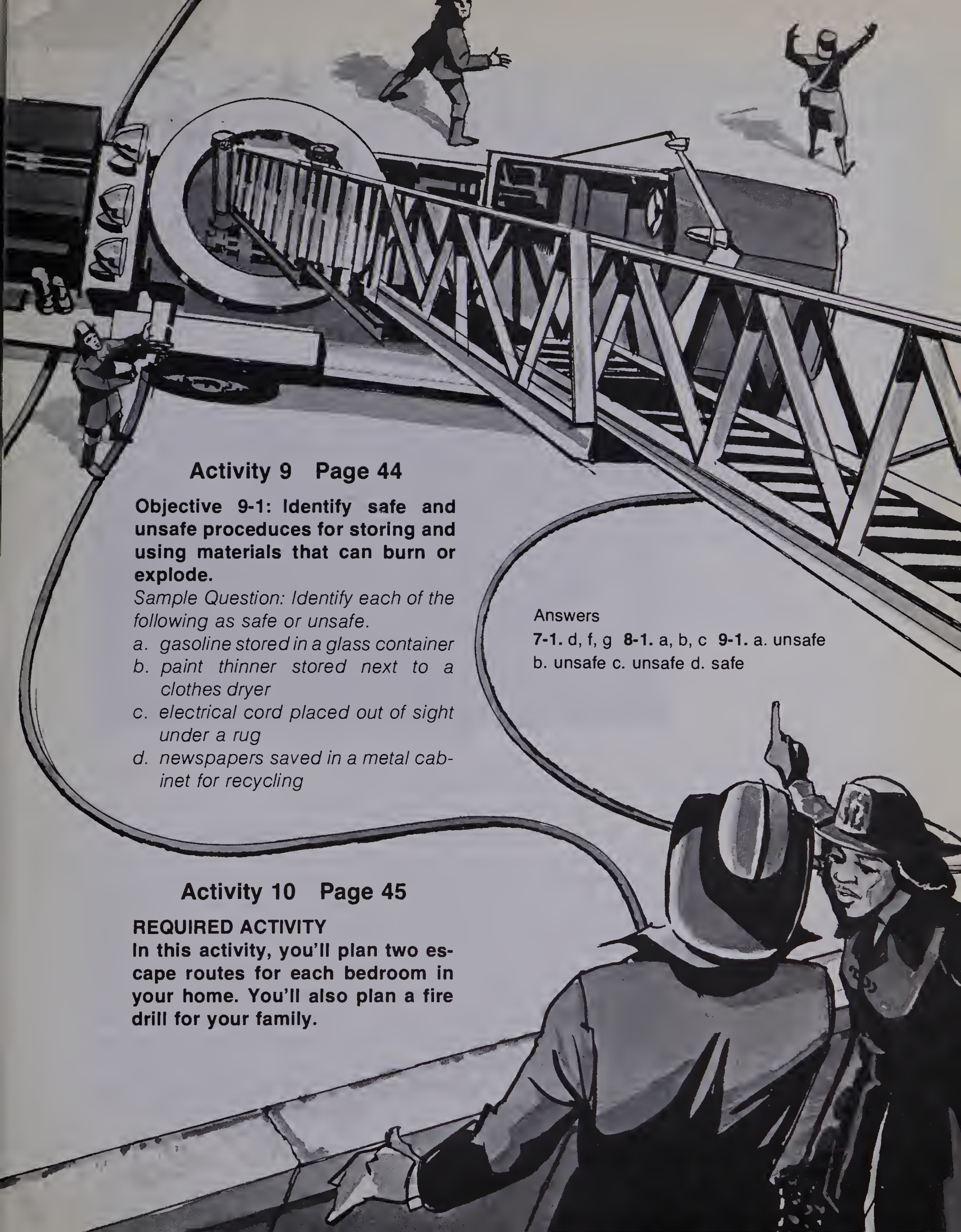
a. heart attack
b. lung disease
c. shock and panic
d. suffocation
e. injury from falling objects
f. burns
g. smoke inhalation

Activity 8 Page 37

Objective 8-1: Describe the characteristic that is common for all explosions that result from burning, and identify things that can increase the chance of explosions occurring.

Sample Question: Suppose there were solid substances available that burn easily and produce a lot of gas. Which of the following would increase the chance of an explosion occurring?

a. decreasing the amount of enclosed space available for the gases produced during burning
b. breaking the solid substances into tiny pieces and spreading the pieces throughout a closed container
c. igniting the solids within a closed container of oxygen



Activity 9 Page 44

Objective 9-1: Identify safe and unsafe procedues for storing and using materials that can burn or explode.

Sample Question: Identify each of the following as safe or unsafe.

a. gasoline stored in a glass container

b. paint thinner stored next to a clothes dryer

c. electrical cord placed out of sight under a rug

d. newspapers saved in a metal cabinet for recycling

Answers

7-1. d, f, g **8-1.** a, b, c **9-1.** a. unsafe b. unsafe c. unsafe d. safe

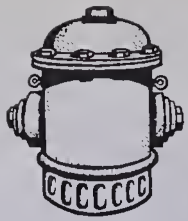
Activity 10 Page 45

REQUIRED ACTIVITY

In this activity, you'll plan two escape routes for each bedroom in your home. You'll also plan a fire drill for your family.

ACTIVITY EMPHASIS: The early phlogiston theory is shown to be inconsistent with the burning reactions. Lavoisier's experiments are described, and experiments are performed to demonstrate the role of oxygen in burning and the conservation of mass.

MATERIALS PER LAB GROUP
See Materials and Equipment, pp. TM 3-6.



Activity 2
Whatever Happened to Phlogiston?

You've probably watched many things burn. Did you ever wonder what happens during burning? Try the following investigation. You'll need just one thing — a match. (Wear safety goggles for this.)

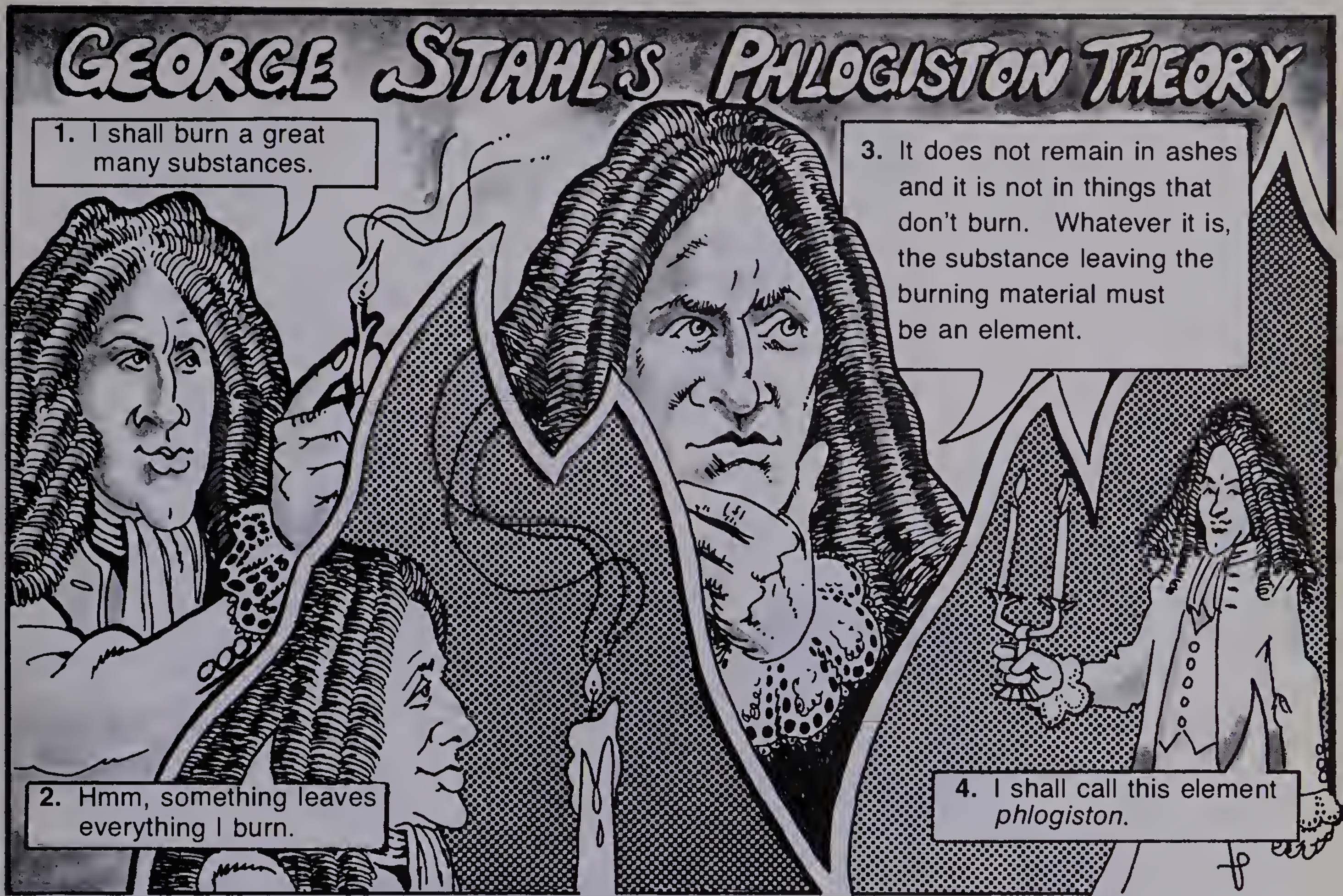
Light the match and observe it burning. (Don't let it burn too long!)

2-1. Something seems to leave. Explanations will vary, but many will cite the smoke, heat, and maybe even light that leave the burning match.

• 2–1. Did something seem to enter or leave the match as it burned? Explain your answer.

Burning was one of the first things that one group of scientists (now called chemists) questioned. Scientists have many questions. And they do a lot of quessing about the answers to their questions. Scientists usually base their guesses on reasons. In fact, there's a special name for a guess that's based on good reasons and much evidence. It's called a *theory*.

For thousands of years, people have wondered about the makeup of things. People once believed that each different kind of thing was not related to any other kind of thing. For example, copper, iron, brass, and gold were not related to each other. Then there was a theory that all matter could be reduced to only four elements — earth, air, fire, and water. Another theory concerned burning. A scientist named George Stahl studied the burning of many substances.



• 2–2. According to Stahl's phlogiston [flow-JIS-tun] theory, is phlogiston in
a. wood, paper, and coal?
b. the wood ashes left after a fire?
c. glass or stones?

2-2. (a) yes; (b) no; (c) no.

• 2–3. According to the phlogiston theory, everything that burns contains the same element. True or false?

2-3. True.

According to the phlogiston theory, things that are able to burn contain phlogiston. Wood ashes, glass, and stones do not have phlogiston. That's the reason they will not burn. But the phlogiston theory does not tell us what elements *are* in those things that don't burn. The theory is concerned only with burnable substances.

Phlogiston theory: "When ambient air becomes saturated with the evolved phlogiston, the flame is extinguished."

As far as it goes, the phlogiston theory seems like a good one. It's purpose was to explain what happens during burning. According to the theory, when a substance burns, phlogiston leaves the substance and goes into the air. Stahl also believed that the air can hold only so much phlogiston. If the air happens to be full of phlogiston, nothing more can burn in the air.

Do the following investigation to test the phlogiston theory. See if the air can be filled with phlogiston. You'll need about 30 minutes for the investigation. And you'll need to use a balance. If you don't know how to use a balance, do *Resource Unit 10*. Then get the following items:

safety goggles
small (birthday) candle
asbestos pad
matches
jar or beaker, taller than candle
balance
steel wool

A. Light a match and melt some wax from the bottom of the candle onto the asbestos pad. Then put the candle upright in the wax on the pad.

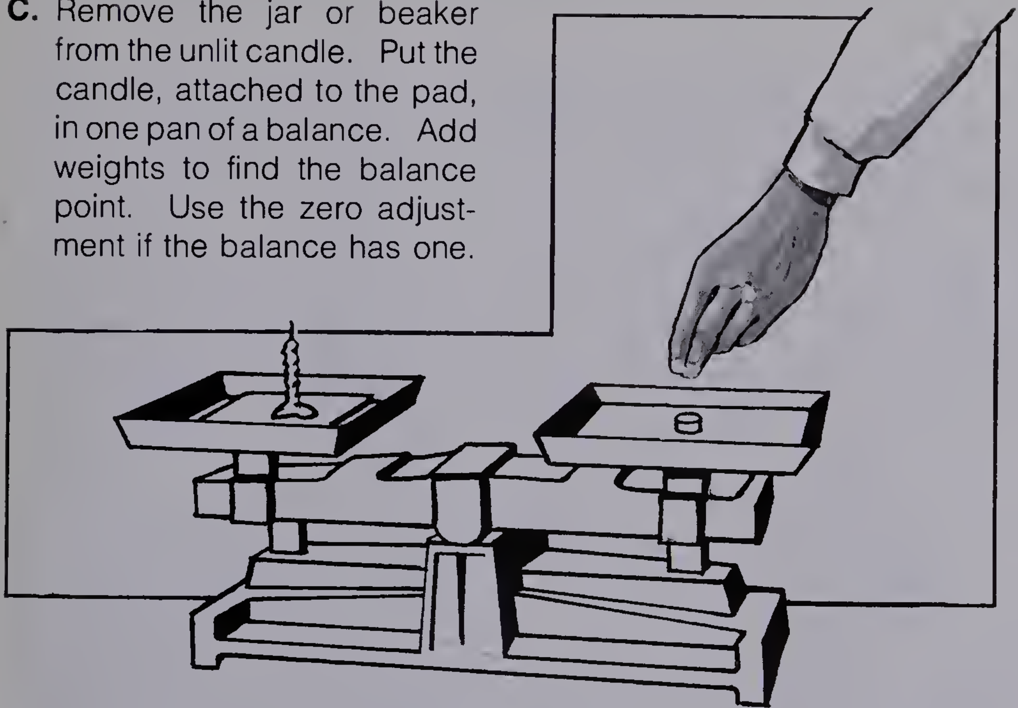
B. Light the candle. Put a jar or beaker upside down over the candle.

2-4. The candle went out. The air became filled with phlogiston and nothing could burn in it, so the candle went out.

• 2 –4. What finally happens to the burning candle? Use the phlogiston theory to explain what you observed.

Now test the theory in another way. Do Steps C, D, and E.

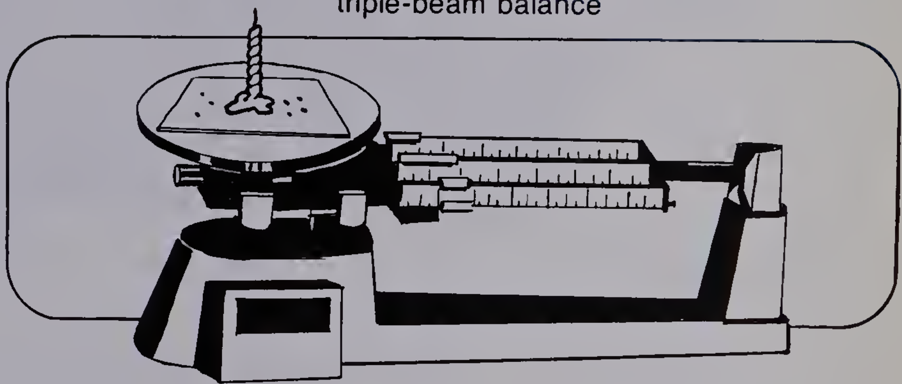
C. Remove the jar or beaker from the unlit candle. Put the candle, attached to the pad, in one pan of a balance. Add weights to find the balance point. Use the zero adjustment if the balance has one.



A double-pan balance will enable detection of weight change. However, if an initial-minus-final weight change is to be determined, a more precise balance should be used (e.g., a triple-beam balance).

D. Keep the candle where it is and light it. After the candle burns for about 10 minutes, blow it out.

triple-beam balance



E. If you're using a triple-beam balance, or if you have small weights, find the weight of the candle and pad together. Otherwise, check the pointer to see how much the weight changed.

• 2–5. What was the total weight of the candle and pad *before* the candle was lighted (Step C)?

2-5. Answers will vary.

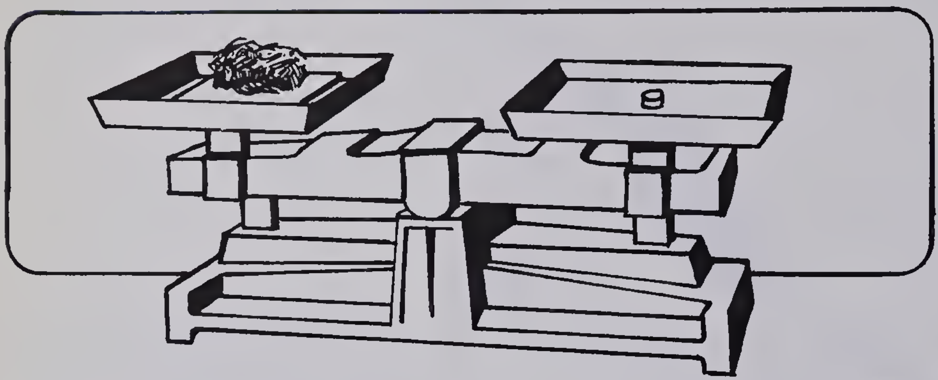
• 2–6. *After* the candle was lighted (Steps D and E), was the total weight of the candle and pad *more*, the *same*, or *less* than before the candle was lighted? Use the phlogiston theory to explain your observation.

2-6. Less because the candle lost phlogiston.

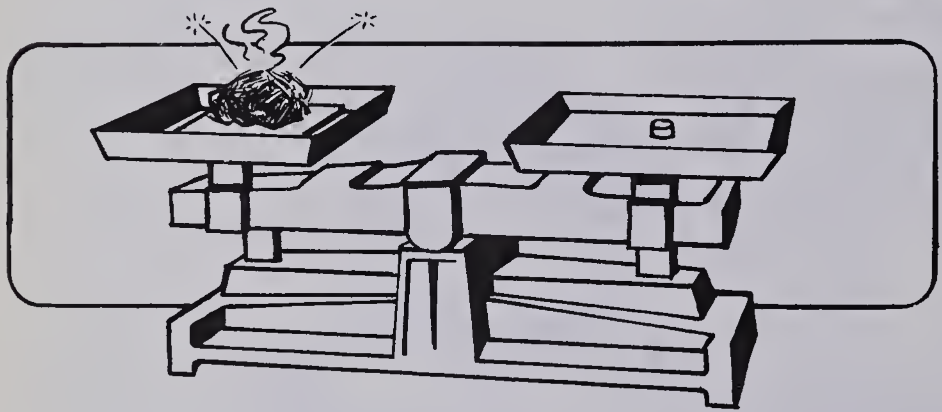
So far, the phlogiston theory does a pretty good job. Maybe the candle flame did go out because the air inside the jar became full of phlogiston. And maybe the candle lost weight because phlogiston left the burning candle. But a theory must be tested many times and in many ways.

The steel wool "ball" must be very loosely packed.

Test the phlogiston theory again. This time use a ball of loosely-packed steel wool. (Steel is mostly iron, and iron will burn.)



F. Put the piece of steel wool on the asbestos pad. Then place the steel wool with the pad in one pan of a balance. For accuracy, use a triple-beam balance if available. Adjust the weights to find the balance point, or adjust the balance to zero.



G. Keep the steel wool where it is and light it. In a few seconds, the steel wool should stop burning. Relight the steel wool again and again until it fails to burn when you touch a match to different places on it. Then let the steel wool cool for about a minute.

2-7. Answers will vary.

• 2-7. What was the total weight of the steel wool and the pad *before* the steel wool was lighted?

2-8. Answers will vary.

• 2-8. When the steel wool stopped burning and cooled, what was the total weight of the steel wool and pad?

2-9. If done carefully, it will weigh *more.*

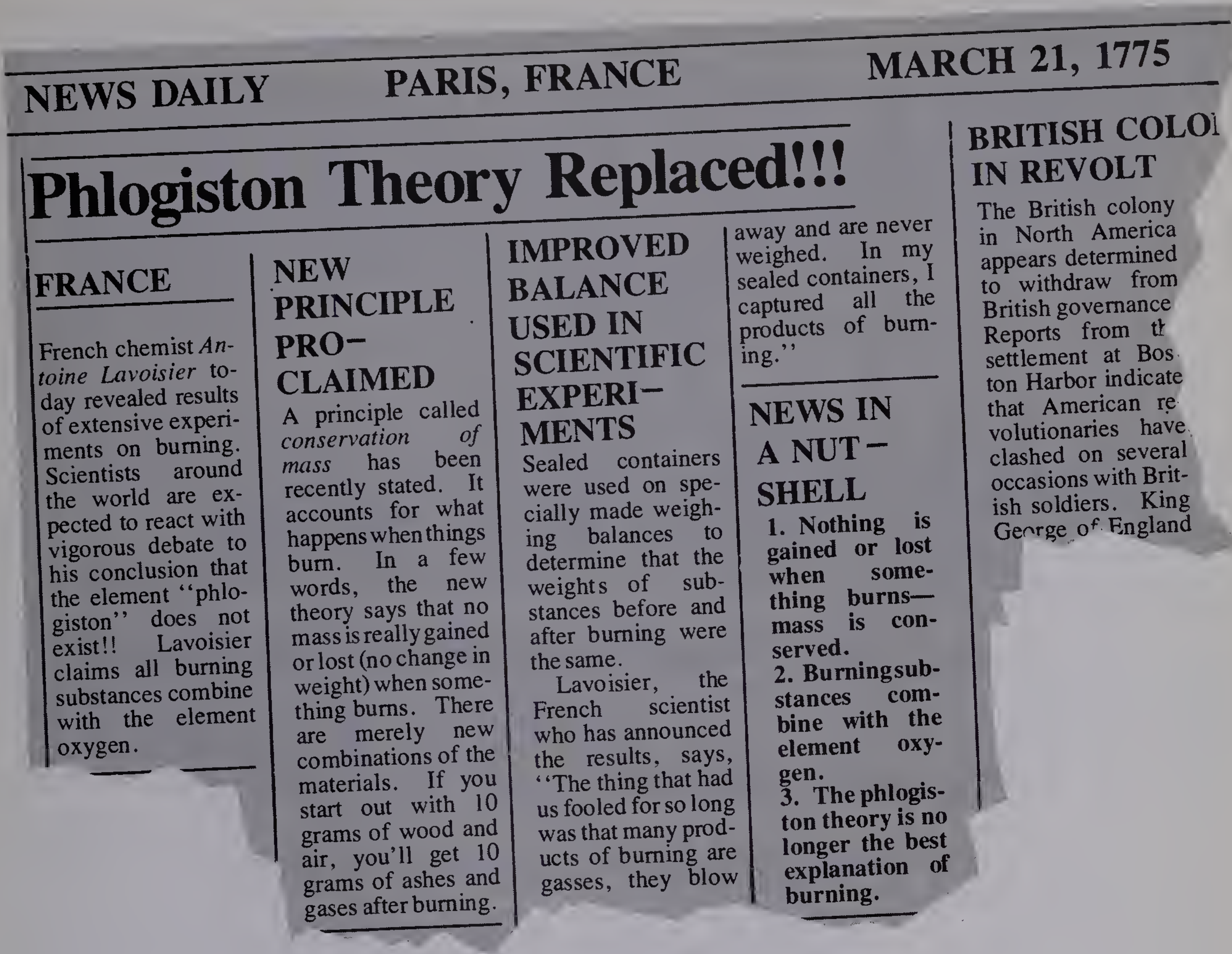
• 2-9. After the steel wool was lighted, did it weigh *more,* the *same,* or *less* than before it was lighted?

Successful results of the steel wool investigation can be achieved by (1) very careful execution on a double-pan balance, or (2) employing a precise, laboratory balance (i.e., a triple-beam balance) for final-minus-initial weight determination.

When the steel wool investigation is carefully done, a gain in weight is observed. If you didn't get this result, it would be a good idea to repeat Steps F and G.

The steel wool gained weight when it burned. Something must have been added to it. Does the phlogiston theory explain this? No, the phlogiston theory predicted a weight *loss* because phlogiston leaves a burning substance. Investigations like this one finally caused Stahl's phlogiston theory to be rejected.

Today, chemists have a different theory about burning. The current theory was first developed about two hundred years ago by the French chemist Antoine Lavoisier [Lav-WAZ-e-ay]. Study the newspaper stories shown in Figure 2-1.



NEWS DAILY PARIS, FRANCE MARCH 21, 1775

Phlogiston Theory Replaced!!!

FRANCE

French chemist *Antoine Lavoisier* today revealed results of extensive experiments on burning. Scientists around the world are expected to react with vigorous debate to his conclusion that the element "phlogiston" does not exist!! Lavoisier claims all burning substances combine with the element oxygen.

NEW PRINCIPLE PROCLAIMED

A principle called *conservation of mass* has been recently stated. It accounts for what happens when things burn. In a few words, the new theory says that no mass is really gained or lost (no change in weight) when something burns. There are merely new combinations of the materials. If you start out with 10 grams of wood and air, you'll get 10 grams of ashes and gases after burning.

IMPROVED BALANCE USED IN SCIENTIFIC EXPERIMENTS

Sealed containers were used on specially made weighing balances to determine that the weights of substances before and after burning were the same.

Lavoisier, the French scientist who has announced the results, says, "The thing that had us fooled for so long was that many products of burning are gasses, they blow away and are never weighed. In my sealed containers, I captured all the products of burning."

NEWS IN A NUTSHELL

1. Nothing is gained or lost when something burns—mass is conserved.
2. Burning substances combine with the element oxygen.
3. The phlogiston theory is no longer the best explanation of burning.

BRITISH COLO[NIES] IN REVOLT

The British colony in North America appears determined to withdraw from British governance. Reports from th[e] settlement at Boston Harbor indicate that American revolutionaries have clashed on several occasions with British soldiers. King George of England

Figure 2–1

★ **2–10. According to Lavoisier, what element combines with burning substances?**

2-10. Oxygen.

★ **2–11. According to Lavoisier, why does it sometimes appear that something is lost when things burn?**

2-11. Some of the burning products are gases which blow away and never are weighed.

★ **2–12. When steel wool burns, it gains weight. Use Lavoisier's theory of burning to explain the weight gain.**

2-12. Oxygen in the air combines with the steel wool (iron) to form a product (iron oxide) that weighs more than the steel wool.

★ **2–13. Describe how Lavoisier's experiments helped to disprove the phlogiston theory.**

2-13. Lavoisier used sealed jars to capture the gaseous products of burning. He weighed the gaseous products along with the solid products and found no gain or loss of weight after burning. This helped to disprove that phlogiston was released during burning.

Lavoisier's theory of burning is called the *oxygen theory of burning*. Since Lavoisier's time, no experiment has shown the theory to be wrong. So today's chemists continue to believe in the theory.

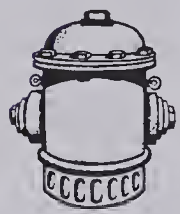
2-14. Burning produces new combinations of the same atoms in the fuel and air. No atoms are destroyed; no atoms are created.

★ **2–14. Describe how the law of conservation of mass applies to burning.**

This may be the first time you've met the law of conservation of mass. If so, don't worry if the meaning isn't completely clear. You'll study conservation of mass again in other minicourses. But if you've seen this law before, and are feeling uneasy about it, you may want to read *Resource Unit 18*. It describes conservation of mass in more detail.

ACTIVITY EMPHASIS: Many common substances are combustible, some are also flammable, and some are noncombustible. Substances are tested to determine in which category of burning they belong.

MATERIALS PER LAB GROUP
See Materials and Equipment, pp. TM 3-6.
See also Advance Preparation, p. TM 7.



Activity 3
To Burn or Not

Many substances will burn, and many won't burn. Some things ignite (start to burn with a flame or glow) easily, and some ignite with difficulty. Usually you can't tell just by looking at a substance whether or not it will burn. To find out whether some substances burn, do the following investigation. It will take about 30 minutes and you'll need these items:

safety goggles
Bunsen burner
matches
tongs or tweezers
asbestos pad or metal lid
Burning Set
teaspoon
notebook
paper towel

CAUTION **Avoid breathing any of the gases produced in the burning tests.**

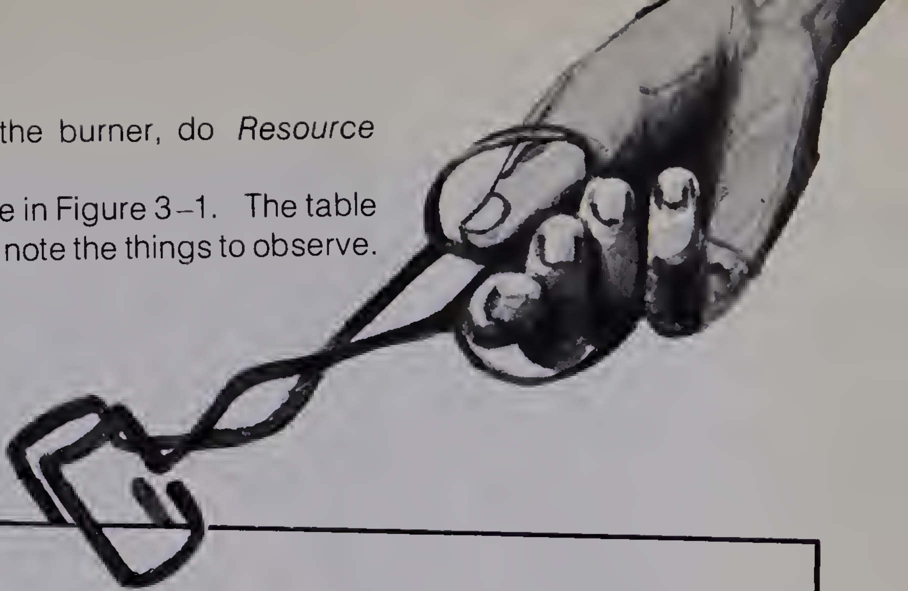
When burning, many substances produce harmful gases that you may not be able to see or smell. To be safe, use small amounts of substances for the burning tests.

3-1. Some products of burning are harmful.

• 3 –1. Why should you avoid breathing smoke or fumes produced in the burning tests?

If you need help in using or adjusting the burner, do *Resource Unit 17.*

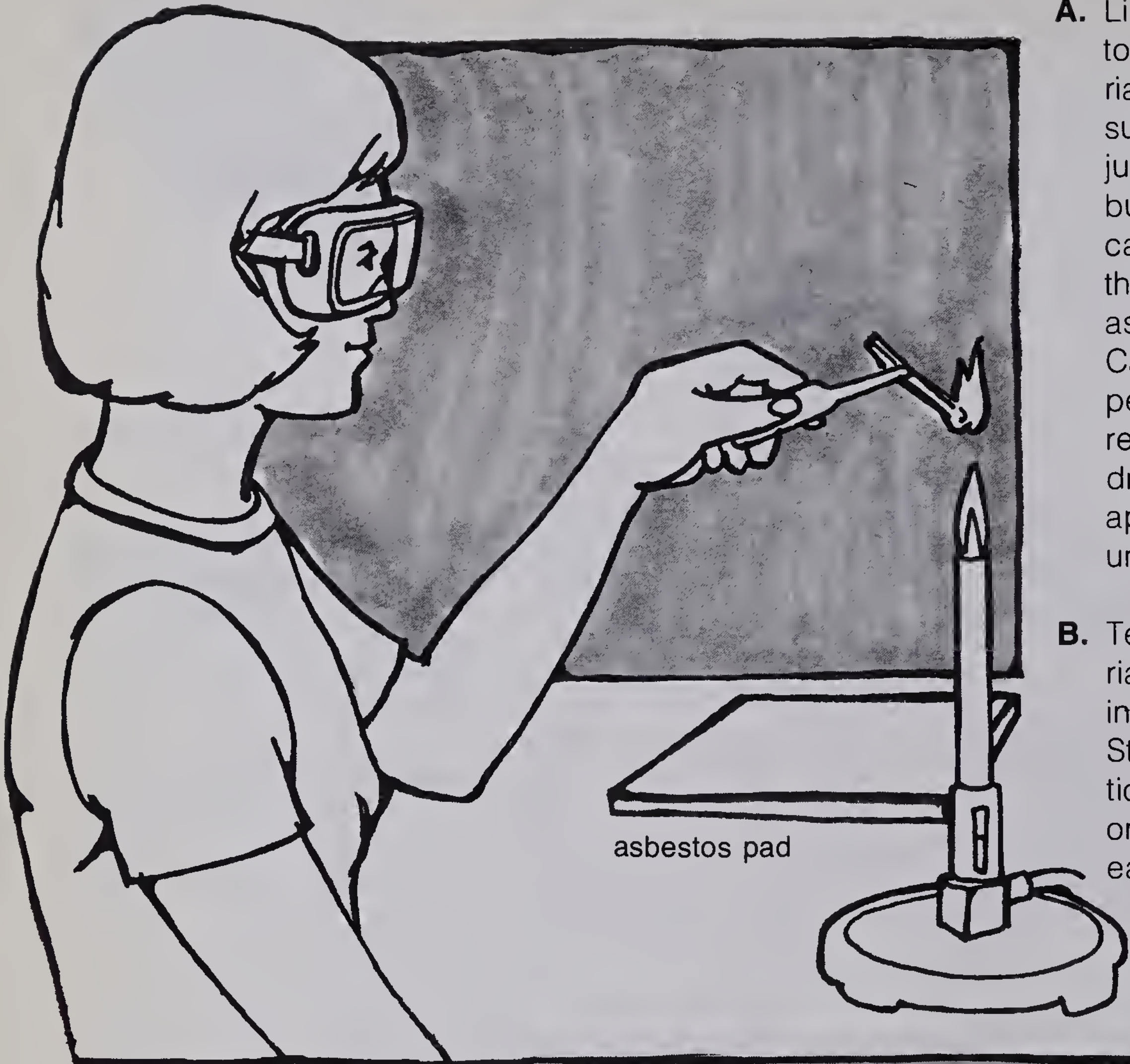
In your notebook, draw a table like the one in Figure 3–1. The table will be your observation record, so carefully note the things to observe.



Locations of check marks will vary depending on the nature of the substances and the conditions of burning. Likely results are shown.

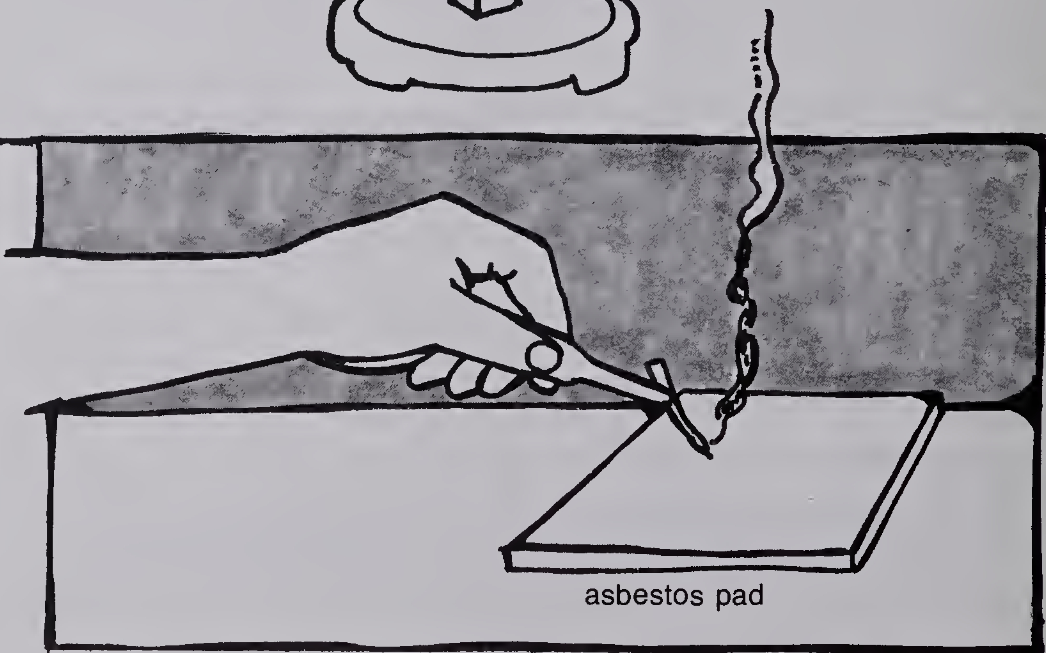
OBSERVATION RECORD						
SUBSTANCES TESTED	**1. EASY TO START BURNING**	**2. HARD TO START BURNING**	**3. CONTINUES BURNING WHEN FLAME IS REMOVED**	**4. STOPS BURNING WHEN FLAME IS REMOVED**	**5. CHANGES BUT DOESN'T BURN**	**6. UNCHANGED BY FLAME**
Nail						✓
Paper	✓		✓			
Plastic	✓	(or ✓)	✓	(or ✓)		
Block of wood		✓	✓			
Leather		✓	✓	(or ✓)		
Styrofoam cup	✓		✓			
Carpeting				✓		
Cloth	✓	(or ✓)	✓	(or ✓)		
Drapery fabric				✓		
Chalk						✓
Table salt					✓	
Table sugar	✓		✓			

Figure 3–1



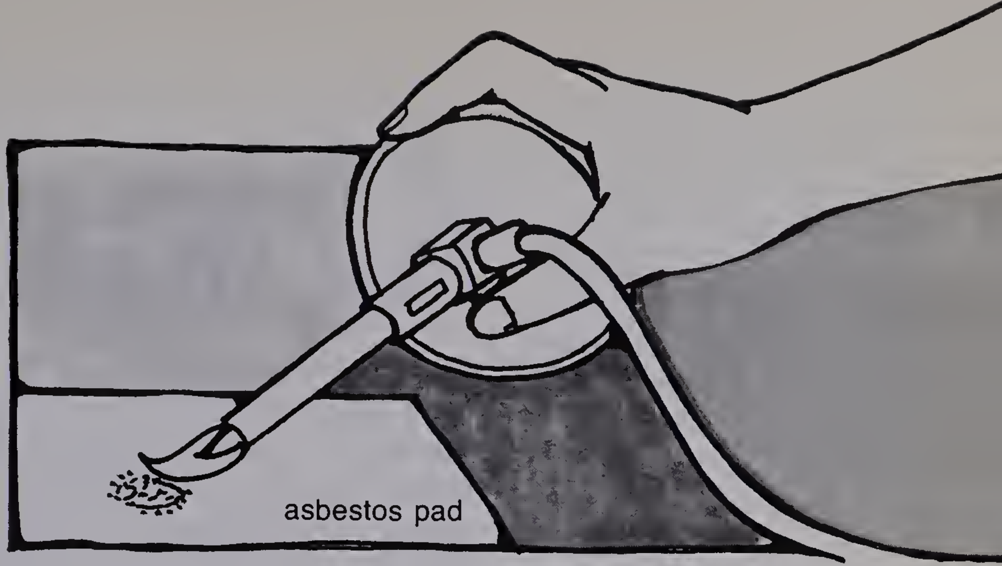
A. Light the burner. Using tongs, grasp one of the materials to be tested (not the sugar or salt) and hold it just above the tip of the burner flame. If the material catches fire, remove it from the flame and hold it over the asbestos pad or metal lid. Carefully observe what happens to the material. Then record what you observed by drawing a check mark in the appropriate column or columns in your table.

B. Test each of the other materials except the sugar and salt in the manner described in Step A. Record all observations in your table. Check only one or two boxes for each material tested.



CAUTION **Use a Bunsen burner, *not* an alcohol burner, for Step C.**

C. Place a spoonful of salt on the asbestos pad. Light the burner and try to ignite the salt. Observe what happens to the salt and record your observation in the table. (Check only one or two boxes.) Use the paper towel to wipe the salt off the asbestos pad. Then test the sugar the same way that you tested the salt.



A substance is *flammable* if it catches fire and continues to burn when the flame is removed. A substance is *combustible* if it catches fire. If a substance does not burn, it is *noncombustible.*

• 3–2. List noncombustible substances besides stones and glass.

3-2. Answers will vary but may include bricks, cement, metal, asbestos, etc.

★ **3–3. Look at the table in Figure 3–1 (page 13). In which columns (1 through 6) would you find observations for**
a. combustible substances?
b. flammable substances?
c. noncombustible substances?

3-3. (a) 1, 2, 3, 4; (b) 1, 3; (c) 5, 6

• 3–4. Consider the materials that you tested. Which ones are
a. combustible?
b. flammable?
c. noncombustible?

3-4. (a) paper, plastic, wood, leather, sugar, Styrofoam, carpeting, cloth, drapery fabric; (b) paper, wood, cloth, others may or may not be flammable, depending on their makeup; (c) nail, salt, chalk.

For Question 3–4, you may have had difficulty deciding whether materials are just combustible or whether they're *both* combustible and flammable. If you had difficulty, refer to your answer to Question 3–3 for help.

★ **3–5. In your notebook, make three columns. Label one column *combustible*, one *flammable*, and the third *noncombustible*. Then, in the appropriate column, list each of the following materials. (Some materials may be listed in more than one column.)**

a. water	**g. dry leaves from a tree**
b. sand	**h. leather**
c. table salt	**i. bricks**
d. newspaper	**j. asbestos pad**
e. concrete	**k. gasoline**
f. candle wick	**l. Styrofoam coffee cup**

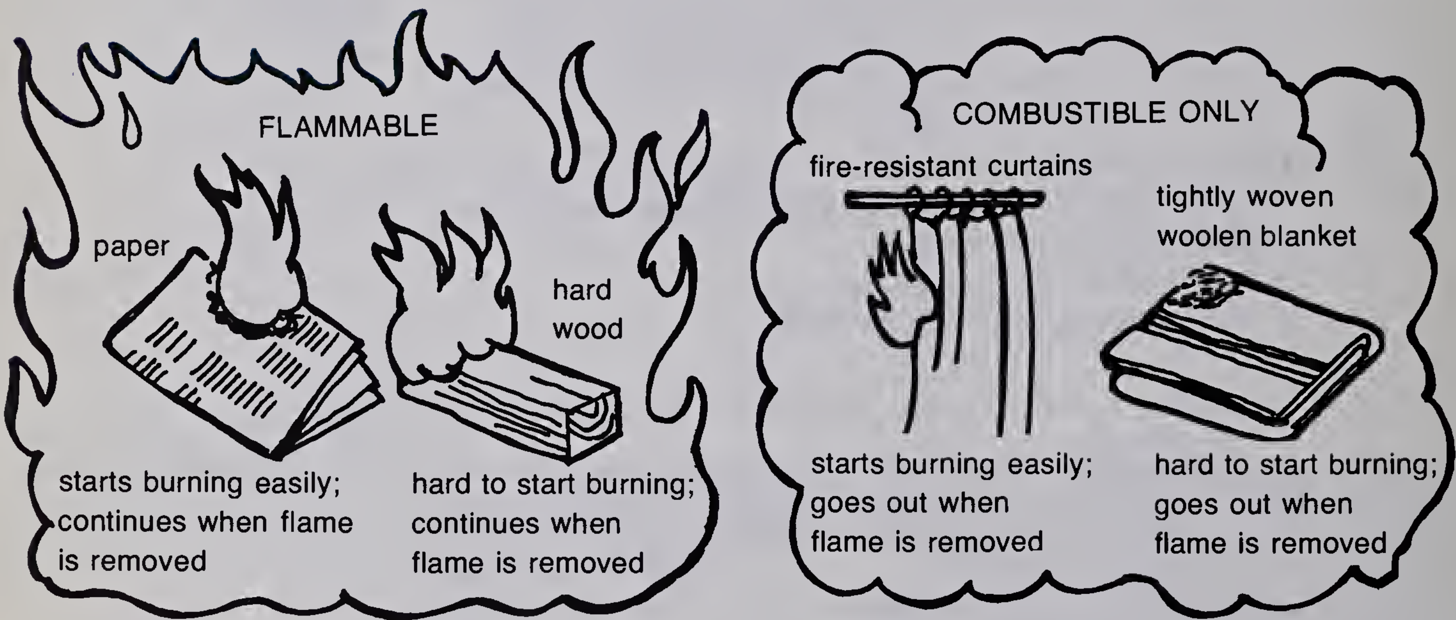
3-5. *Combustible:* d, f, g, h, k, l; *flammable:* d, f, g, k, l; *noncombustible:* a, b, c, e, i, j

ACTIVITY EMPHASIS: The three conditions necessary for burning are: the presence of fuel and oxygen plus a high enough temperature (heat energy) to raise the fuel to its ignition point.

MATERIALS PER LAB GROUP
See Materials and Equipment, pp. TM 3-6.
See also Advance Preparation, p. TM 8.

Activity 4
What's Needed?

You've probably seen lots of fires. Do you know what's needed to keep a fire going? *Fuel* is one thing that a fire needs. A fuel is any substance that is combustible or flammable. A *combustible* substance will ignite (start to burn with a flame or glow). A *flammable* substance will ignite and then continue to burn when the flame is removed. Many substances are both combustible and flammable (paper, for example). Some substances are combustible only. They will ignite but will not continue to burn when the flame is removed.



4-1. Any substance that is combustible or flammable.

• 4–1. Define the term *fuel*.

When a fuel burns, there's a flame or a glow that may be yellowish, bluish, or some other color. If the fire is big enough, you may feel the heat that is given off.

Many different fuels are present all the time. But these fuels certainly aren't burning all the time. There must be something else that's needed in order to have a fire.

4-2. It must be heated to its ignition point.

• 4–2. What is needed to ignite a fuel?

Every combustible substance must be heated to a certain temperature before it can burn. That certain temperature is called the *ignition point* of the substance.

The following investigation shows some things that affect the ignition point. You'll need to use a Bunsen burner in the investigation. If you don't know how to light or adjust a Bunsen burner, do *Resource Unit 17* now. Then do the investigation. You'll need about 30 minutes and these items:

- safety goggles
- asbestos pad
- 2 pieces of paper, each 3 cm × 6 cm
- 2 pieces of cardboard, each 3 cm × 6 cm
- 2 pieces of cloth, each 3 cm × 6 cm
- 2 burette clamps (without plastic or rubber sleeves)
- 2 support stands
- Bunsen burner
- matches
- watch or clock with second hand
- notebook

In your notebook, draw a table like the one in Figure 4–1. You'll be recording your observations in the table.

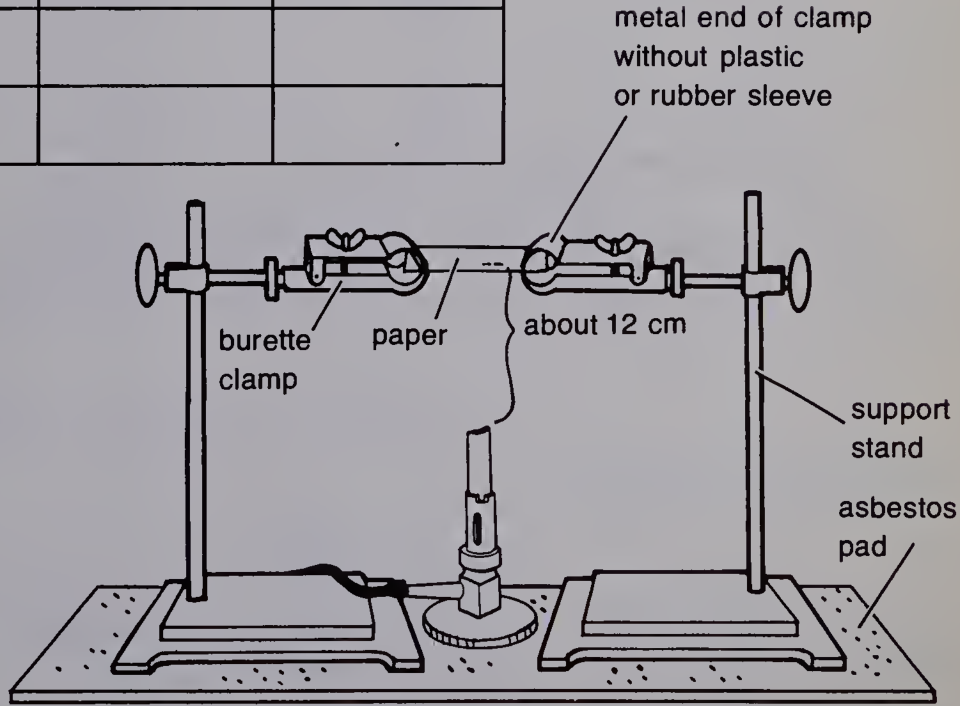
IGNITION POINTS

MATERIAL	IGNITION TIME		
	TRIAL 1	TRIAL 2	AVERAGE
Paper			
Cardboard			
Cloth			

Figure 4–1

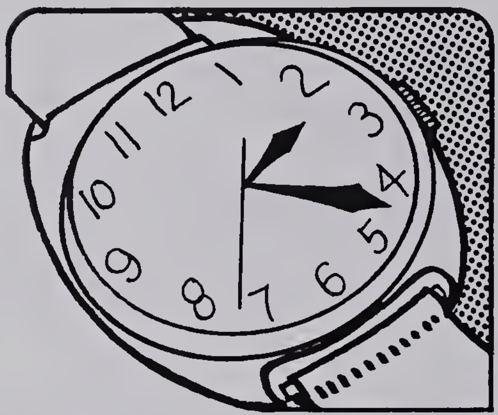
A. Set up the equipment as shown. Adjust the clamps and support stands so that the paper is tightly stretched about 12 cm above the burner.

B. Remove the burner from under the paper. Light the burner and adjust it for the hottest flame.



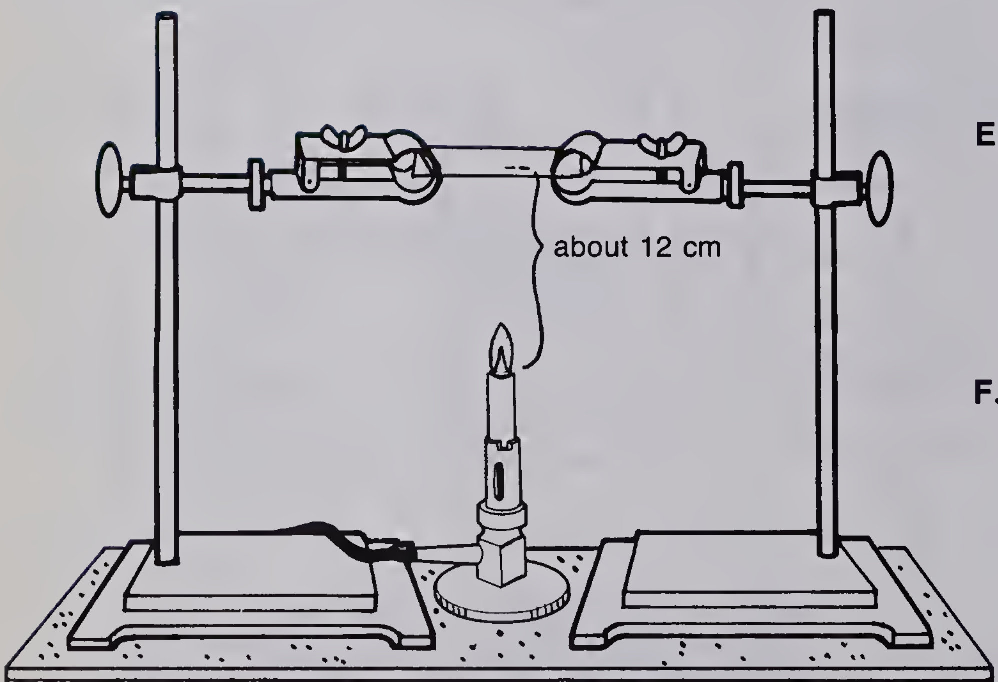
CAUTION **Use care when handling the materials and equipment. They may be very hot.**

If the paper does not ignite properly, these are possible adjustments the students can make: (1) If the paper doesn't ignite after 30 seconds, remove the burner; lower the clamps about 3 cm (using an asbestos glove or pot holder); replace the paper with a new piece; return the burner and start timing again. (2) If the paper ignites as soon as the burner is moved under it, remove the burner; raise the clamps about 3 cm (using an asbestos glove or pot holder); replace the burned paper with a new piece; return the burner and start timing again.



C. Place the lighted burner under the paper. Begin timing. When the paper ignites, stop timing. Let the paper fire burn out — it will take only a few seconds. If the paper doesn't ignite, or if it ignites immediately, discuss the problem with your teacher.

D. In the *Trial 1* column of your table, record the total time it took for the paper to ignite.



E. Repeat Steps A-C with a second piece of paper. This time record the total time for the paper to ignite in the *Trial 2* column of your table.

F. Using a piece of cardboard, do Steps A-C twice. Then, using a piece of cloth, do Steps A-C twice. In each case, record the first result in the *Trial 1* column of your table; record the second result in the *Trial 2* column.

For each material tested, find and record the average for the two trials. If you have trouble with averaging, do *Resource Unit 1*.

4-3. Answers may vary, but the paper will probably ignite the fastest.

• 4–3. Which material (paper, cardboard, or cloth) ignited the fastest?

4-4. Answers may vary, but the cardboard will probably ignite the slowest.

• 4–4. Which material (paper, cardboard, or cloth) ignited the slowest?

The temperature of a substance rises as the substance is held over a flame (like a frying pan when first put on a stove). The longer it takes for a substance to ignite, the higher is the ignition point of the substance.

• 4 –5. Which material (paper, cardboard, or cloth) had the highest ignition point?

4-5. Answers may vary, but should be consistent with the answer to Question 4-4 (the material that ignited the slowest).

Paper and cardboard are basically the same substance. However, they differ in thickness.

• 4 –6. Which material (paper or cardboard) ignited faster?

4-6. Paper.

• 4 –7. Which material (paper or cardboard) had the higher ignition point?

4-7. Cardboard.

• 4 –8. A fuel has an ignition point. Describe what is meant by a fuel's ignition point.

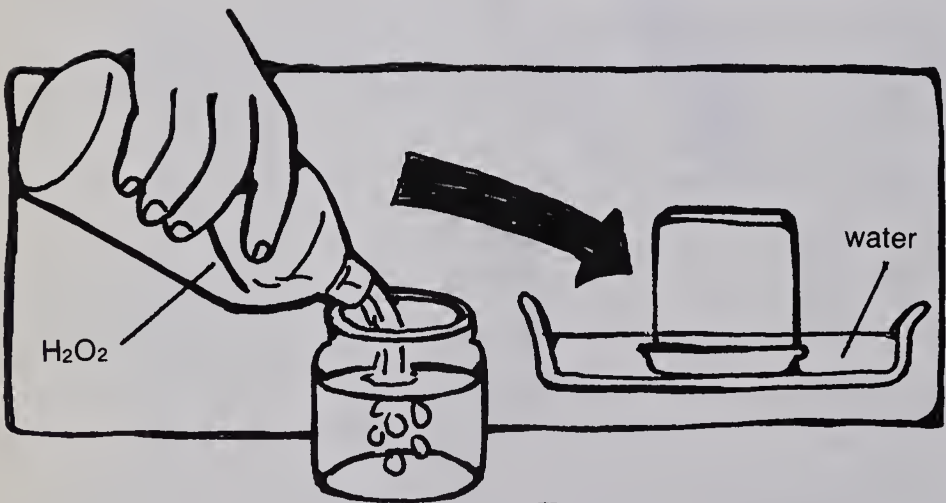
4-8. It is the temperature to which the fuel must be raised in order to ignite.

You've found that there are at least two things that are necessary to have a fire. In addition to *fuel,* the *temperature* of the fuel must be raised enough for it to ignite. But is this all that is needed? No. Air is also needed. Or, more specifically, the *oxygen gas* in air is needed.

You can see how oxygen affects burning by doing the following investigation. You'll need at least one class period and these items:

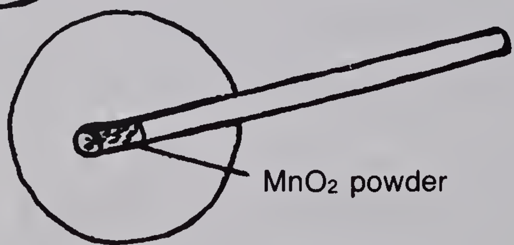
safety goggles
small jar with lid
hydrogen peroxide, H_2O_2, 3% solution
shallow pan with lip
soda straw
manganese dioxide, MnO_2, powder
Bunsen burner
matches
tongs or tweezers
charcoal

IMPORTANT **The H_2O_2 and MnO_2 are used to prepare oxygen gas. Before starting the investigation, check with your teacher to see if a different method for preparing gas is preferred.**



A. Fill the jar to the brim with H_2O_2. Place the lid on the jar. Tighten the lid securely.

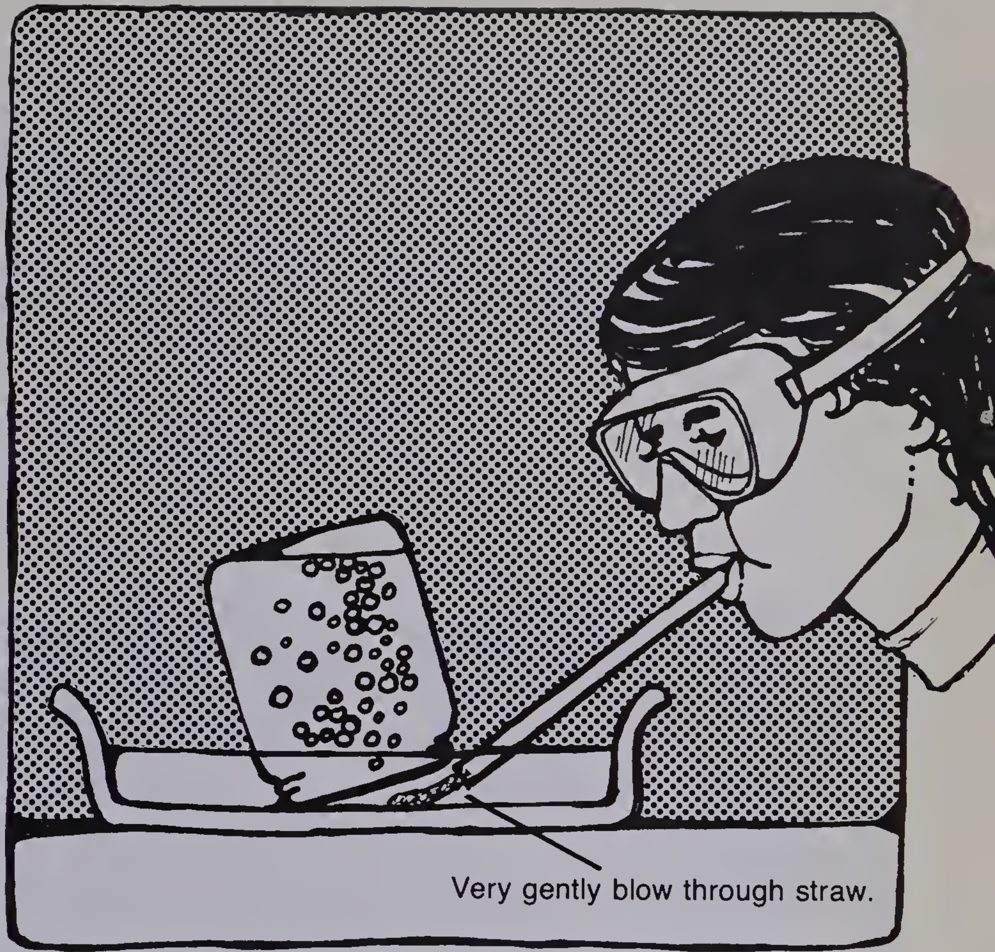
B. Add water to the pan. The water should be about 2 cm deep. Place the jar, lid down, into the water. The jar should be standing upside down on the bottom of the pan.



C. Hold the straw upright and dip it into the MnO_2 powder. The powder should be about 2 cm deep in the straw. Carefully set aside the straw. Don't spill the powder.

CAUTION **In Step D, breathe only through your nose while the straw is in your mouth.**

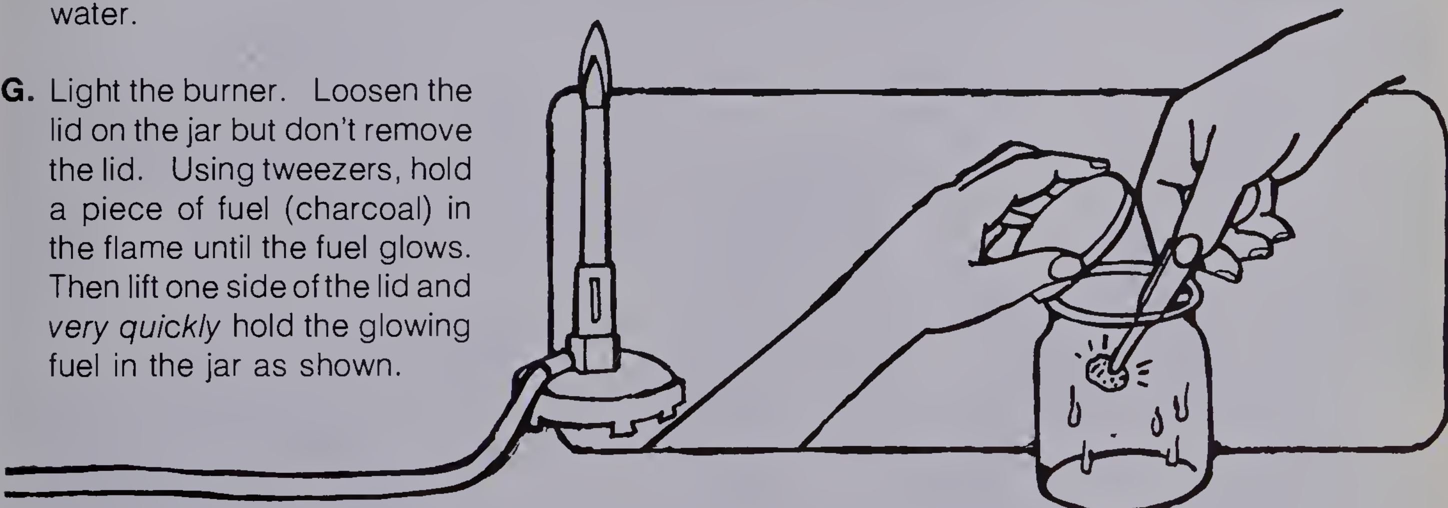
D. While keeping the neck of the jar underwater, remove the lid and set it aside. Then carefully place the powder-end of the straw beneath the neck of the jar. Keep the neck of the jar and the end of the straw in the water. *Very gently* blow through the nonpowder-end of the straw until the MnO_2 powder is removed.



E. When bubbling begins inside the jar, stand the jar upside down on the bottom of the pan. It will take about 15-20 minutes for the jar to fill with gas. During this time, work on another activity. Then do Step F.

F. After 15-20 minutes, replace the jar lid while holding the neck of the jar underwater. Then remove the jar from the water.

G. Light the burner. Loosen the lid on the jar but don't remove the lid. Using tweezers, hold a piece of fuel (charcoal) in the flame until the fuel glows. Then lift one side of the lid and *very quickly* hold the glowing fuel in the jar as shown.



Charcoal is combustible. It's a common fuel. You may have used it for backyard cooking. Charcoal is mostly carbon. When it burns, the carbon combines with oxygen. But charcoal by itself won't burn — even if you put it in pure oxygen.

• 4 – 9. Suppose you have fuel (charcoal) and oxygen. What else do you need in order to achieve burning?

4-9. Enough heat energy to raise the temperature of the fuel to its ignition point.

4-10. It glowed brightly and burned for a second or two.

• 4–10. Describe what happened to the fuel when you put it into the jar.

4-11. The burning charcoal used up the oxygen gas in the jar. A fire can't exist without oxygen.

• 4–11. Why doesn't the fuel continue to burn brightly after it is placed in the jar?

4-12. Air provides oxygen needed for burning; heat energy raises the temperature of the fuel to the fuel's ignition point.

★ **4–12. A fuel must be present for a fire to occur. Fuel is the thing that burns. Why must air and heat energy also be present?**

The more oxygen present, the faster a fire will burn. As a matter of fact, in the presence of pure oxygen, some substances can burn explosively. This is why extra precautions must be taken in areas where pure oxygen is being used.

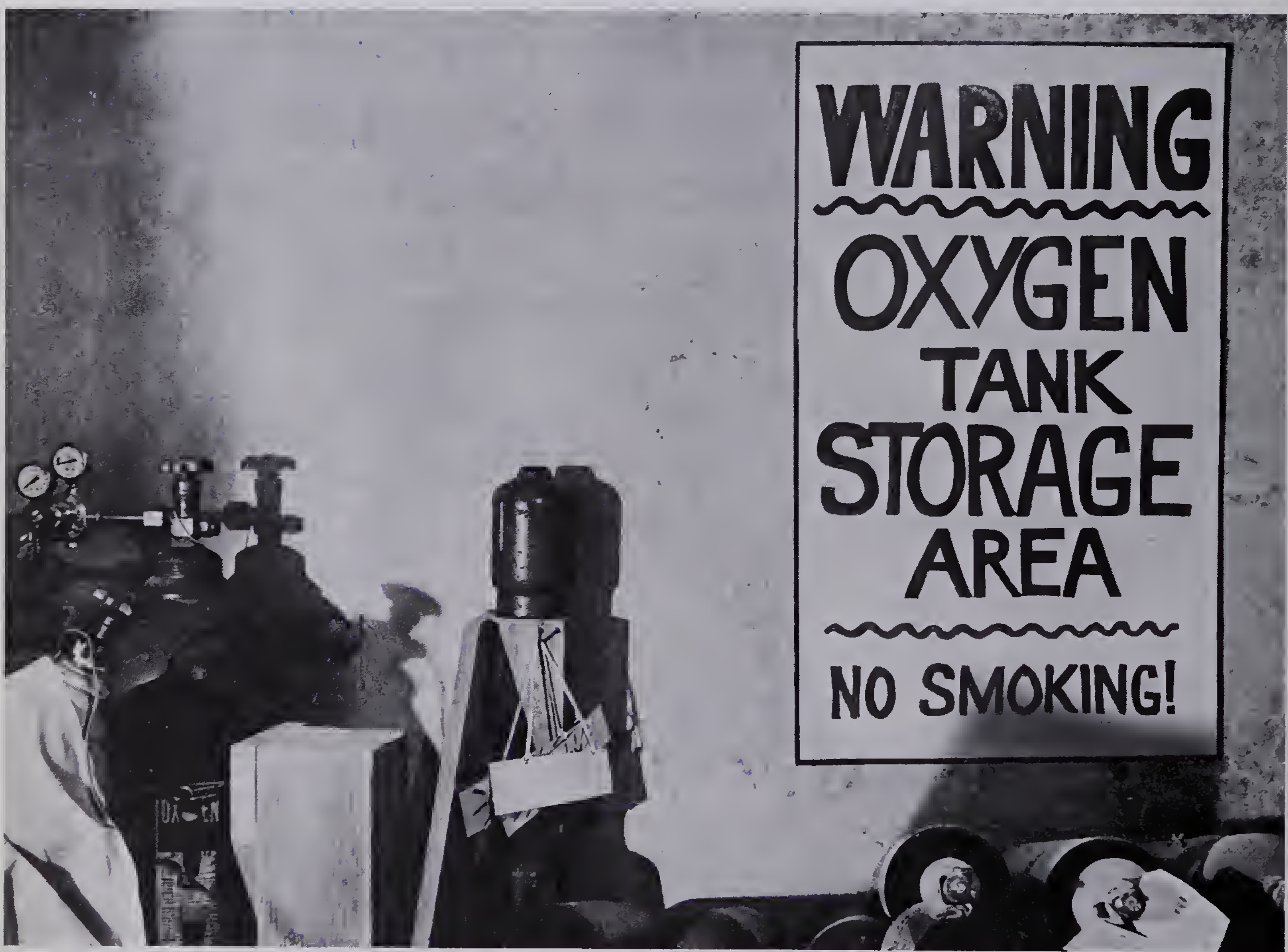


Figure 4–2

4-13. Pure oxygen is stored. The heat energy and/or sparks of a lighted cigarette, cigar, pipe, or match can be very dangerous.

• 4–13. In Figure 4–2, why is the sign posted?

Activity 5
Burning and New Combinations

ACTIVITY EMPHASIS: The process of burning is discussed in terms of conservation of matter (atoms). The products of a burning reaction equal the reactants in terms of numbers of atoms.

MATERIALS PER LAB GROUP
See Materials and Equipment, pp. TM 3-6.

Substances are made up of atoms. When substances are different, their atom-combinations are different. This means that the substances may have different kinds of atoms, different combinations of the same kinds of atoms, or different combinations of different atoms. Figure 5—1 shows some substances and their atom-combinations. Do *Resource Unit 22* if you need help with Figure 5—1.

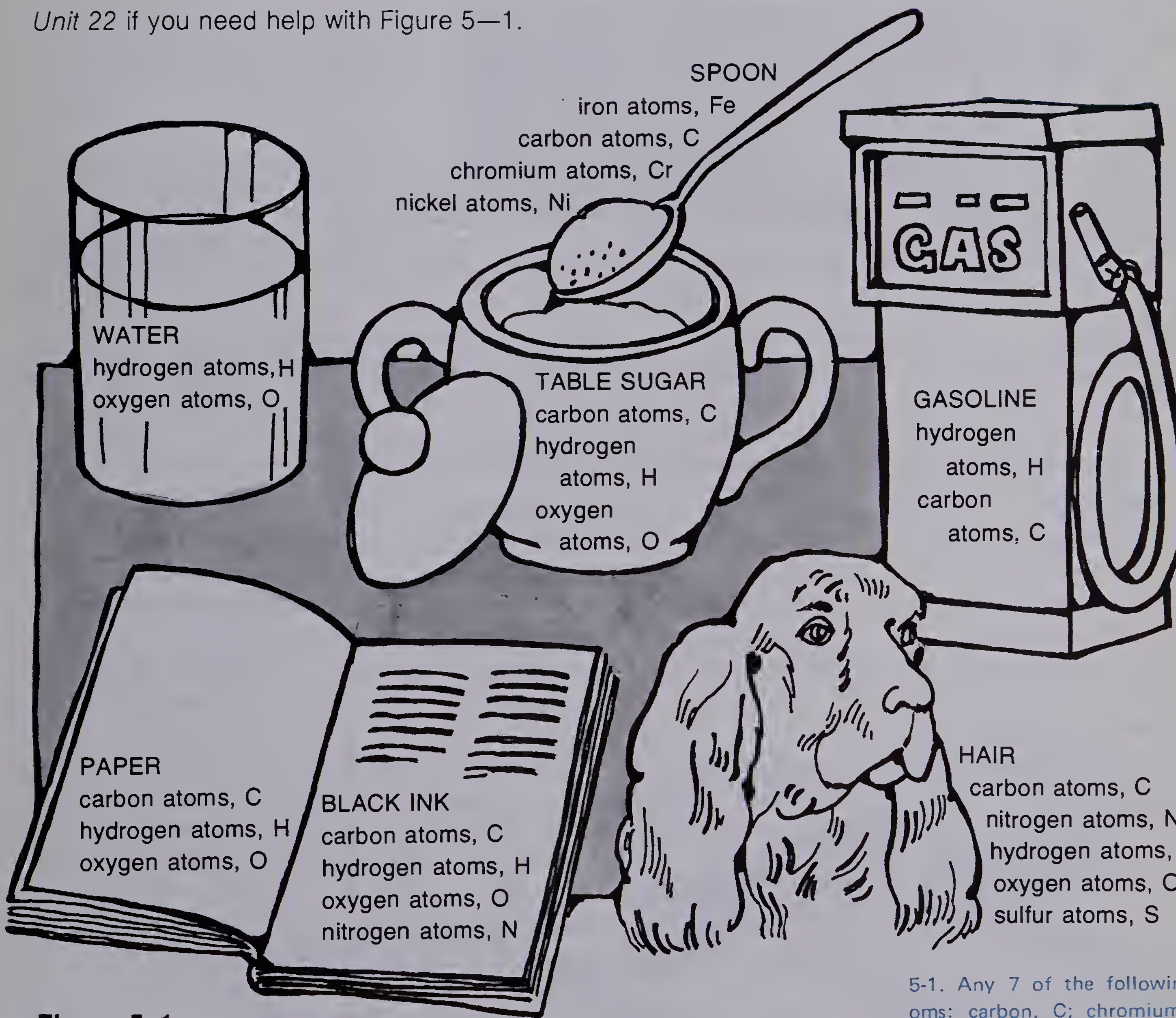


Figure 5–1

- 5 –1. Name seven atoms found in common substances.

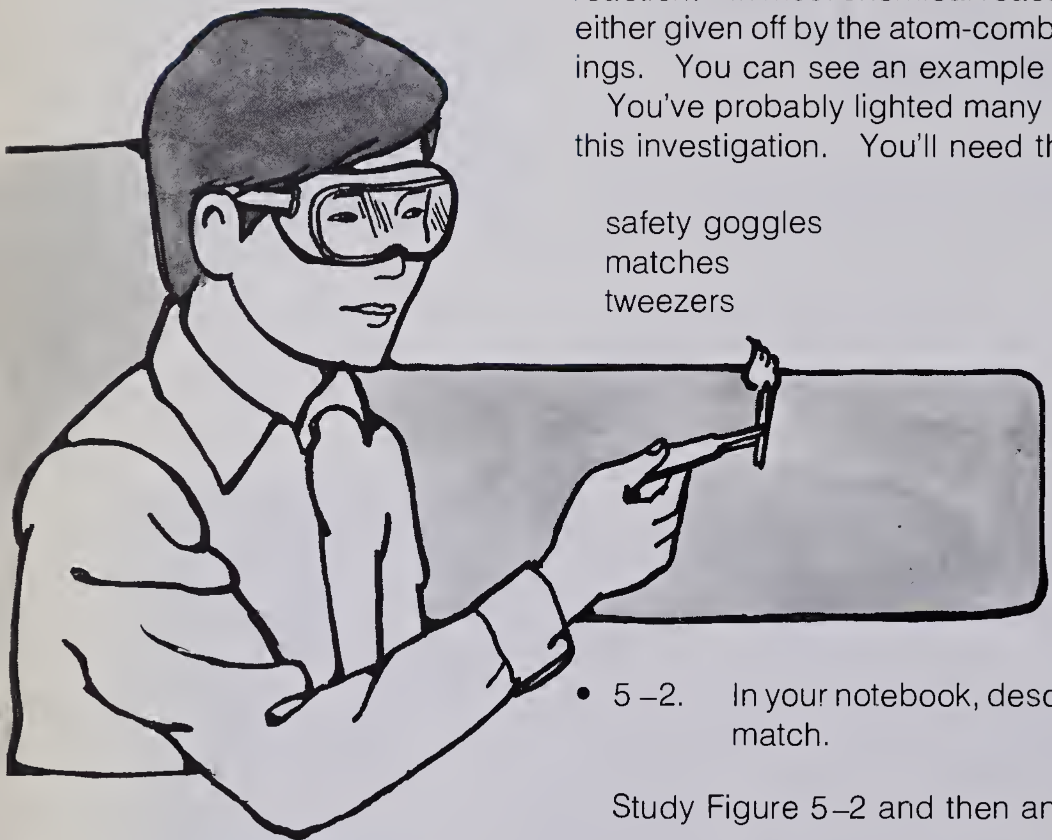
5-1. Any 7 of the following atoms: carbon, C; chromium, Cr; iron, Fe; hydrogen, H; nitrogen, N; nickel, Ni; oxygen, O; sulfur, S.

The head of a match contains a mixture of various materials including phosphorus, glue, ground glass, chlorate, and potash. These materials cause the head of the match to ignite at a lower temperature than if they were not present. Also, a match stick (or splint) is dipped in paraffin to improve the quality of burning of the wood.

Sometimes combinations of atoms get taken apart and new combinations are formed. This kind of change is called a *chemical reaction*. In most chemical reactions, heat energy is involved. Heat is either given off by the atom-combination or taken in from the surroundings. You can see an example of this.

You've probably lighted many matches. You'll light another one in this investigation. You'll need the following items:

safety goggles
matches
tweezers



A. Light a match. Grasp the bottom of the burning match with tweezers.

B. Observe the match until it stops burning.

• 5-2. In your notebook, describe your observations of the burning match.

Study Figure 5-2 and then answer Questions 5-3, 5-4, and 5-5.

5-2. Answers will vary.

Life Story of a Match

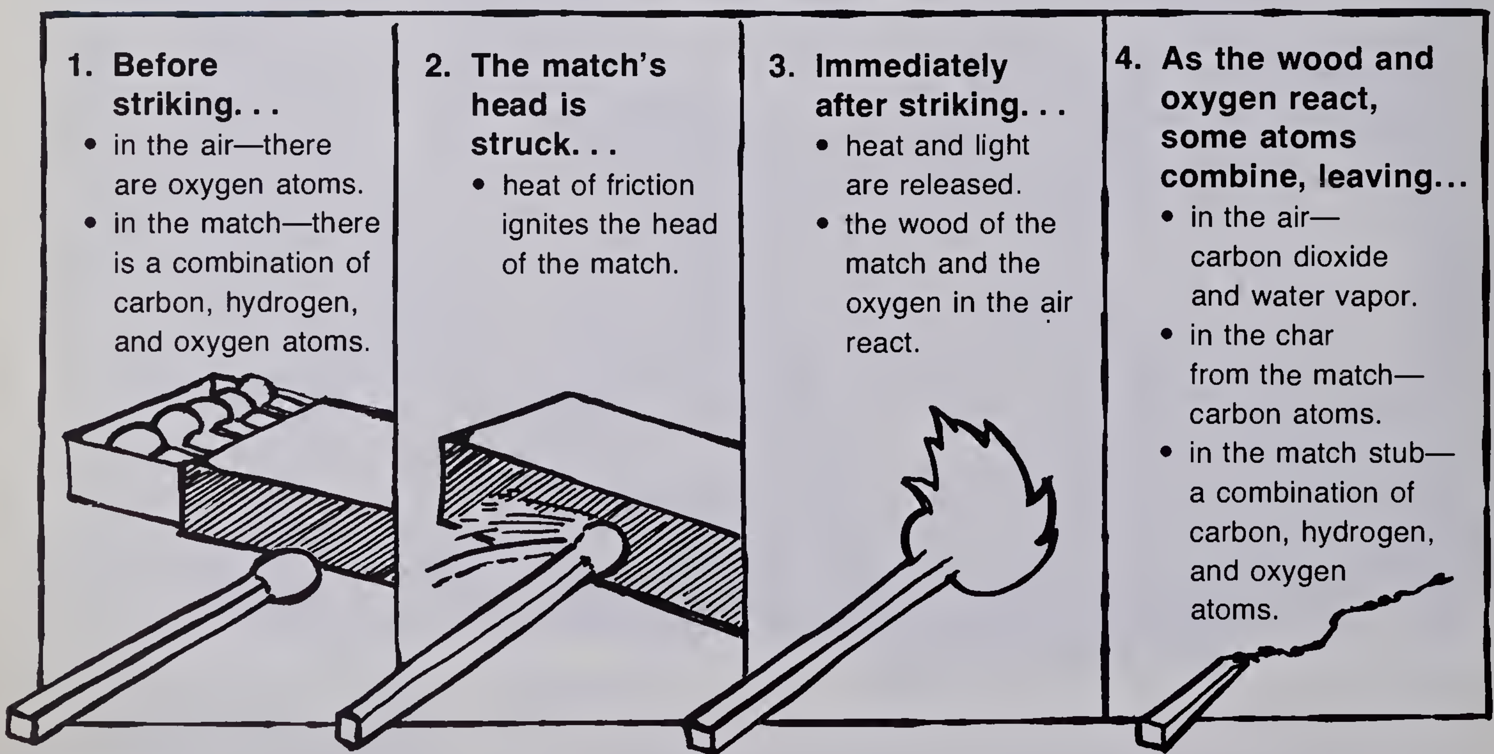


Figure 5-2

• 5 –3. Name two substances involved in a chemical reaction during the burning of a match.

5-3. The wood of the match and the oxygen gas in the air.

• 5 –4. Heat energy is needed to start a match burning. Where does that heat energy come from?

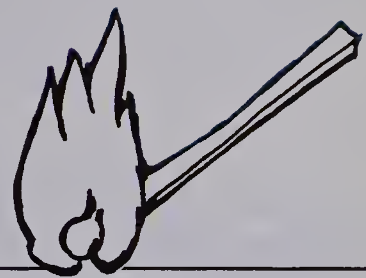
5-4. From *striking* the head of the match – heat of friction causes ignition.

★ **5–5. Do new atom-combinations occur when the wood of a match burns? If so, what are the new combinations?**

5-5. Yes. Carbon dioxide, water vapor, carbon.

Burning is the rapid combination of oxygen atoms with the atoms in a fuel (a burnable substance). This chemical reaction produces heat energy and light energy which can be seen and felt. It also produces new substances called *products.*

The new products have atom-combinations that are different from the original atom-combinations in the fuel. Figure 5–3 shows what happens to the atoms of fuel and oxygen gas during the burning of a match.



THE BURNING OF A MATCH

wood for each cellulose part	+	**oxygen**	→	**carbon dioxide**	+	**water**	+	**energy**
$C_6H_{10}O_5$		$6\ O_2$		$6\ CO_2$		$5\ H_2O$		**(heat and light)**
6 carbon atoms linked with 10 hydrogen atoms and 5 oxygen atoms	combines with	12 oxygen atoms (6 pairs of linked oxygen atoms)	to yield (by chemical changes)	6 carbon atoms linked with 12 oxygen atoms	and	10 hydrogen atoms linked with 5 oxygen atoms	and	energy

Figure 5–3

Figure 5–3 shows that there are the same number of atoms of each kind *after* the burning reaction as there are *before* the reaction. But the atoms are rearranged into new combinations. Use Figure 5–3 to answer Question 5–6.

• 5 –6. In the match-burning reaction, how many carbon, hydrogen, and oxygen atoms are there *before* the reaction (to the left of the arrow)? Are there the same number of each atom in the products?

5-6. 6 carbon atoms, 10 hydrogen atoms, 17 oxygen atoms. Yes.

★ **5–7. How does the burning of a substance affect the number of each kind of atom involved in the reaction? Explain.**

5-7. It has no affect on the number of atoms. There is the same number of each kind of atom before and after the reaction.

• 5 –8. What new atom-combinations form when fuels containing carbon and hydrogen are burned?

5-8. The carbon and hydrogen combine with oxygen producing water, H_2O, and carbon dioxide, CO_2.

ACTIVITY EMPHASIS: Fires are extinguished when one of the three conditions necessary for burning is removed; the common methods for extinguishing fires.

MATERIALS PER LAB GROUP
See Materials and Equipment, pp. TM 3-6.
See also Advance Preparation, p. TM 8.

Activity 6
The Wet Blanket

Figure 6–1 shows the three requirements that are necessary for burning to take place. If you keep any one of the three from combining with the other two, the fire will be extinguished (put out). You can stop or control fires by removing either the fuel (any burnable substance) or the oxygen, or by preventing the fuel from reaching its ignition point. (The *ignition point* is the temperature at which the fuel will burn.)

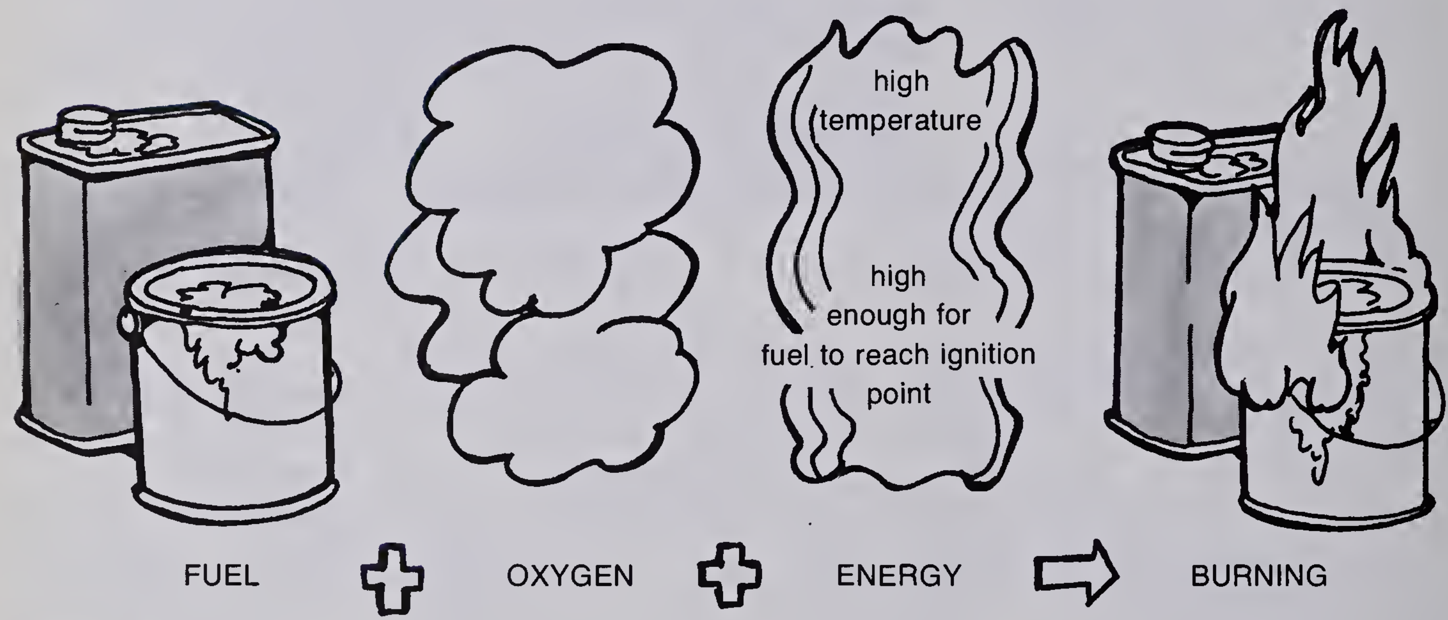
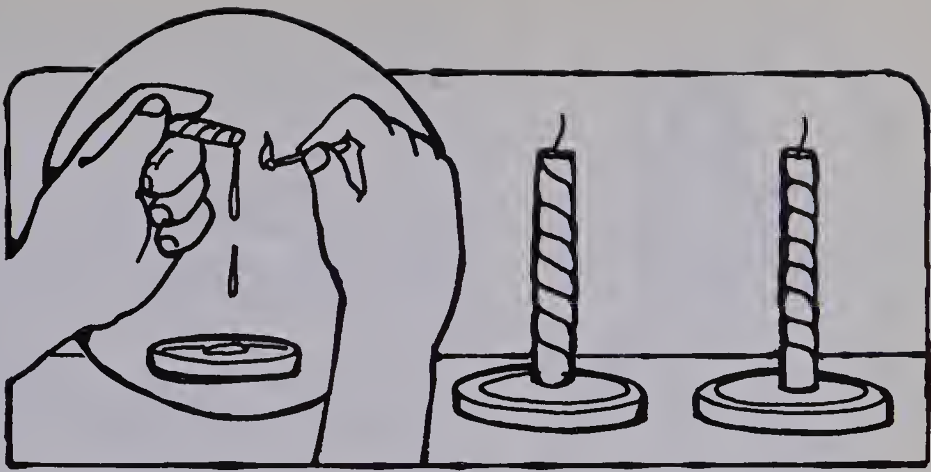


Figure 6–1

What are some examples of the three general ways to control a fire once a fire has started? The following investigation illustrates one example. You'll need about 10 minutes and these items:

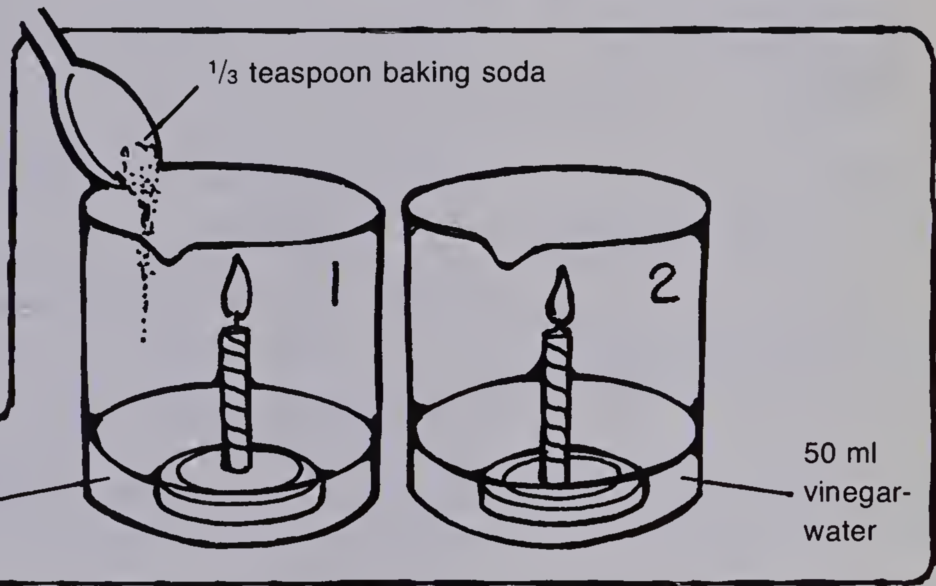
safety goggles
matches
2 candles, short (birthday)
2 beakers or containers, taller than the candles
2 metal jar lids that fit in the beakers
graduated cylinder
vinegar-water
grease pencil for labeling
teaspoon
baking soda

A. Melt some wax from the bottom of one of the candles. Let the wax drip onto the inside of a jar lid. Then place the candle upright in the lid. Do the same for the second candle and lid.



B. Label the beakers *1* and *2*. Add about 50 ml of vinegar-water to each of the two beakers. Then place each candle in a beaker as shown. Don't get the candles' wicks wet!

C. Light each candle. Then carefully drop about 1/3 teaspoon of baking soda into the vinegar-water in Beaker 1. Observe the candles in both beakers.



• 6–1. Describe what happens in Beakers 1 and 2.

6-1. In Beaker 1, the water fizzed and the candle went out. In Beaker 2, nothing happened.

When you added the baking soda, the vinegar-water fizzed Fizzing indicates that a gas is escaping. In this case, the gas is carbon dioxide. Carbon dioxide is heavier than air. It sinks to the bottom of the beaker. The sinking of the carbon dioxide lifts the air with its oxygen up and out of the beaker.

• 6–2. Why do you think the carbon dioxide in Beaker 1 caused the flame to go out?

6-2. Carbon dioxide replaced the air (including oxygen) in the beaker. Since carbon dioxide does not burn, the flame went out.

• 6–3. Which of the three requirements for a fire was removed in Beaker 1?

6-3. Oxygen.

• 6–4. Why was Beaker 2 included in this investigation?

6-4. As an experimental control to show that the candle would not have gone out in that amount of time if the baking soda had not been added.

If you have trouble answering Question 6–4, do the section titled "A Control" in *Resource Unit 15.*

Figure 6–2

6-5. In both cases, oxygen gas (air) is kept away from the fuel.

6-6. The water cools the fuel (wood and shingles), keeping the fuel from reaching its ignition point.

6-7. The fuel is cooled and the steam replaces the air (in effect, the oxygen is removed).

Wrapping a blanket around a person whose clothes are burning is another way to put out a fire.

- 6 –5. How is using a blanket similar to the carbon-dioxide method of extinguishing a fire?

Another way to smother a fire (remove the oxygen) is with water. When water is put on a fire, some steam is produced. Steam and liquid water act like the carbon dioxide did in Beaker 1 of the investigation. They help smother the fire — remove the oxygen.

You've seen that a fire can be put out or controlled by removing oxygen. A second general way to put out a fire is to lower the temperature of the fuel below the fuel's ignition point. Figure 6–2 shows one effective way of lowering the temperature.

- 6 –6. Some people hose down their homes when there is a nearby forest fire. How could this help prevent their homes from burning?

- 6 –7. Suppose you poured water on a wastebasket fire. Describe two ways the water might act to control the burning.

A third general way to put out a fire is to take away the fuel. This method is often used for preventing forest fires from spreading. A *fire lane* is formed by cutting down and removing a strip of trees. This removes the fuel from that strip. The fire burns to one side of the strip and then goes out.

You know that there are three requirements for burning to take place. The requirements are: *fuel, oxygen,* and a *high enough temperature* to cause the fuel to ignite. If any one of the requirements is removed, the fire will be extinguished.

★ **6–8. Suppose you were camping. Describe how you would fully extinguish a campfire by using each of the following methods.**
a. removing the fuel
b. removing the oxygen gas
c. lowering the temperature of the fuel below its ignition point

6-8. Answers will vary. Some possible answers are: (a) by taking away the unburned logs, or by spreading them apart; (b) by putting sand or water (to form steam) on the logs; (c) by putting wet sand or water on the logs.

You have learned about the three primary ways of putting out a fire. It is important that you remember these ways in case of an emergency.

There is a fourth way to put out a fire — by "starving" the flame. This method has been invented recently. The fire is put out by chemicals that interfere with the chemical reactions between the fuel and the oxygen inside the burning flame. This interference stops the fire.

Often you can extinguish a small fire if you have a commercial fire extinguisher and know how to use it. But many people don't know how to use commercial fire extinguishers. In fact, most people think that all fire extinguishers are alike. But they aren't. The label on a commercial extinguisher describes the type of fire for which the extinguisher should be used.

Fires are generally described as Class A, B, or C. (See Figure 6–3.)

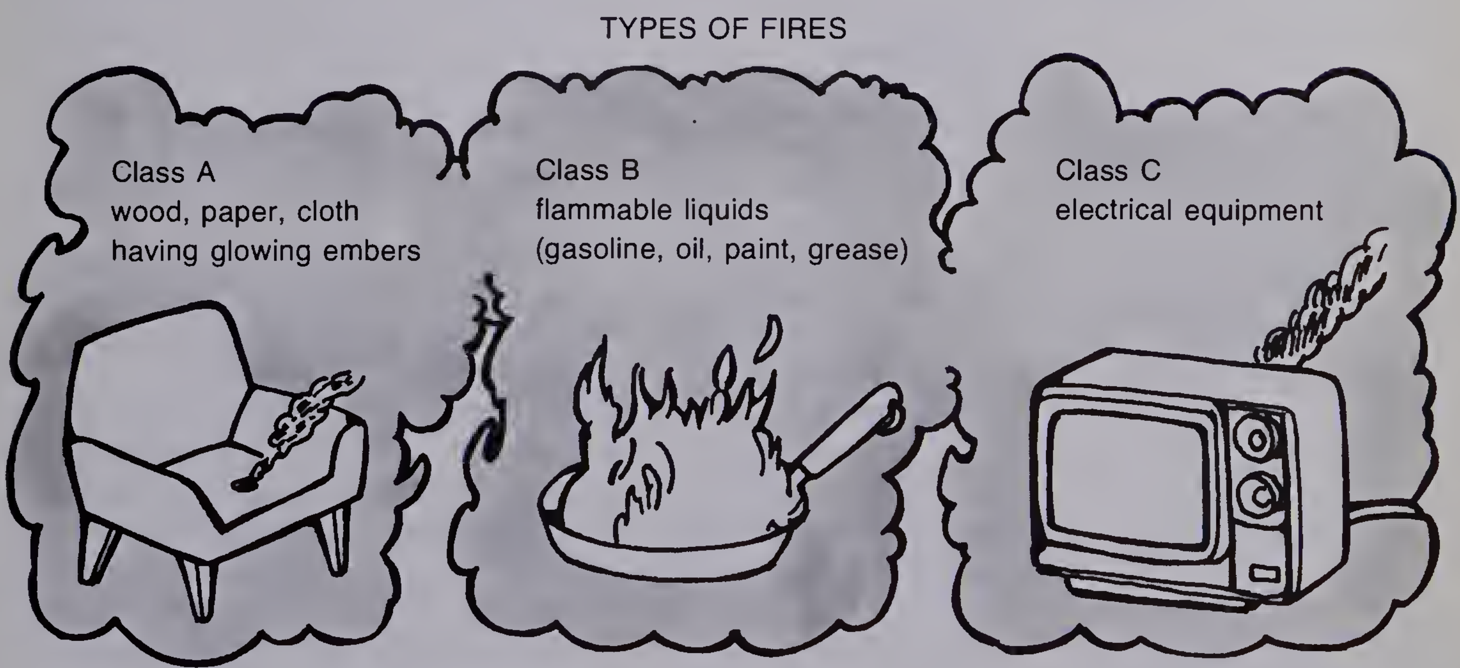


Figure 6–3

Some common types of commercial fire extinguishers are shown in Figure 6–4. If there are any commercial fire extinguishers in your home or school, read their labels. Then you'll know what kinds of fires they can be used against. Using the wrong kind of extinguisher may make a fire worse, produce injuries, or both.

Common Types of Commercial Fire Extinguishers

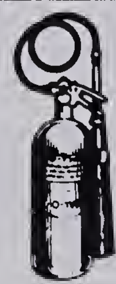
	WATER TYPE			
TYPE	 stored pressure	 cartridge operated	 water pump tank	 soda acid
CLASS OF FIRE USED AGAINST	A			A
TYPE	 foam	 carbon dioxide	 regular dry chemical	 multipurpose dry chemical
CLASS OF FIRE USED AGAINST	B	C	B and C	A,B,C

Figure 6–4

• 6 –9. Name the type(s) of fire extinguisher(s) you have in your home and at school.

6-9. Answers will vary. Many students will say that they don't have fire extinguishers at home. If they have extinguishers, the foam type and multipurpose dry-chemical type are common in homes; the multipurpose dry-chemical type is common in schools.

• 6 –10. Look at your answer to Question 6–9. Name the class of fire that each type of extinguisher can be used against.

6-10. Answers will vary but should be consistent with the answer to Question 6-9.

Some of the newest fire extinguishers contain a liquid called *Halon*. *Halon* puts out a fire in an unusual way. It starves the flame of a fire by interfering with the chemical reactions between the fuel and the oxygen inside the flame. As indicated earlier, this is a fourth way to extinguish a fire.

Of course if you don't have a *Halon*-filled fire extinguisher you'll have to use one or more of the three primary ways to extinguish fires.

• 6 –11. Tell how *Halon* puts out a fire.

6-11. It interferes with the chemical reaction between the fuel and oxygen gas in the air; thus extinguishing the fire.

Suppose there isn't any fire extinguisher available, or the right type of extinguisher isn't handy. There are some substitutes you can use. A number of common materials can be used (see Figure 6–5).

Handy Fire Fighters!

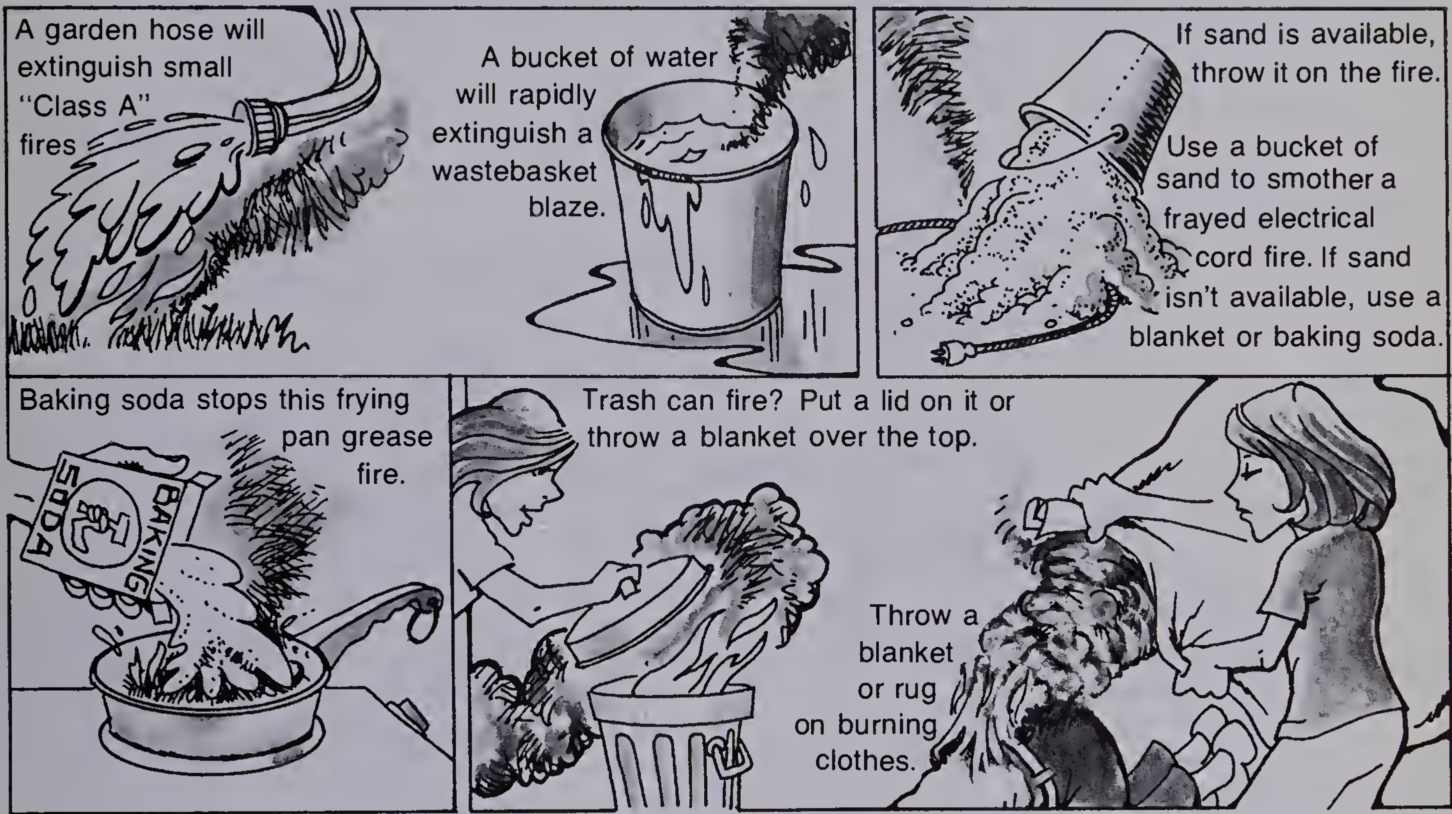


Figure 6–5

• 6 –12. Match each type of fire with the fire fighter that can be used against it.

6-12. a-2,3; b-1,2,4; c-4; d-2,3,4

Type of Fire	Fire Fighter
a. grease fire	1. water
b. wastebasket	2. sand
c. burning clothes on child	3. baking soda
d. frayed electrical cord on floor	4. blanket

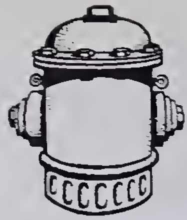
Most people think of water when they want to put out fires. But water on a grease fire can cause the grease to splatter, causing burns and other fires. Water on a gasoline fire can spread the fire because gasoline floats on water. And water on an electrical fire can result in a dangerous electrical shock.

★ **6–13. Why is it important to use the right fire extinguisher?**

6-13. The use of wrong extinguishers can make the fire worse.

ACTIVITY EMPHASIS. Direct and indirect causes of injury and death from fires; ways of avoiding injury during a fire.

MATERIALS PER LAB GROUP
None.



Activity 7
Fire Can Kill

PREDICTION: During the next year, 10,000 or more Americans will die as a result of fire, and 30,000 or more will be seriously injured.

This is not a wild prediction. It only assumes that next year will be like past years. Will you be a fire victim?

Figure 7–1 shows four major causes of death and injury that are directly related to fire. These causes fall into two categories: asphyxiation [as-FIK-see-ay-shun] and burns. Asphyxiation refers to death caused by a lack of oxygen, by the presence of poisonous gases, or by other interferences with normal breathing.

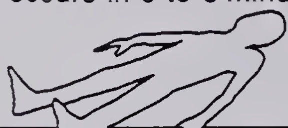
Direct Causes of Injury and Death in Fires

ASPHYXIATION
most frequent cause of death in a fire

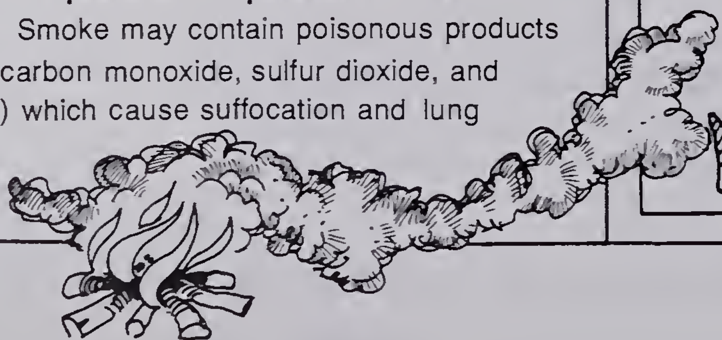
1. Suffocation from lack of oxygen.
Air is normally about 20% oxygen. But fire uses up oxygen from the air.

When air has only—

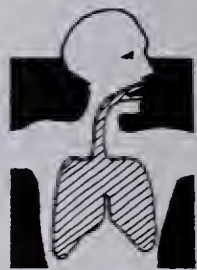
17% oxygen, thinking is an effort, and body coordination is difficult.	16% oxygen, attempts to escape may be the wrong kind and may not work out.
6%–15% oxygen, body coordination is lost, and the onset of fatigue is rapid.	below 6% oxygen, breathing stops; death occurs in 6 to 8 minutes.



2. smoke and poisonous products from burning Smoke may contain poisonous products (such as carbon monoxide, sulfur dioxide, and ammonia) which cause suffocation and lung damage.



BURNS
much less frequent cause of death in a fire



3. high temperature
When temperatures in a fire reach 150°C and above—hot smoke with high moisture burns tissues deep in the lungs. And there is loss of consciousness. Death occurs in minutes.

4. flames (least frequent cause of death in a fire)
Many people do not survive when they have burns on 50% or more of their body.

Figure 7–1

• 7–1. According to Figure 7–1, what is the most frequent cause of death in a fire?

7-1. Asphyxiation.

• 7–2. According to Figure 7–1, what is the least frequent cause of death in a fire?

7-2. Burns.

★ **7–3. List four major ways that a fire can directly cause injury and death.**

7-3. Suffocation from lack of oxygen; asphyxiation due to smoke and poisonous gases; burns due to high temperature; burns due to flames.

Figure 7–2 shows a newspaper story describing a tragic fire.

Local Fire Kills 24; 32 injured

A fire at a local club late last night killed 24 people and injured 32 others. Fire officials said that the building had no smoke or high-temperature detection system and no sprinkler system which might have controlled the fire in its early stages.

One expert said it was a fire which started in the basement but then suddenly flashed explosively when many of the building's materials reached their ignition points. Smoke, lack of oxygen, and flames from the flash-type fire accounted for most of the deaths, according to the county fire investigator.

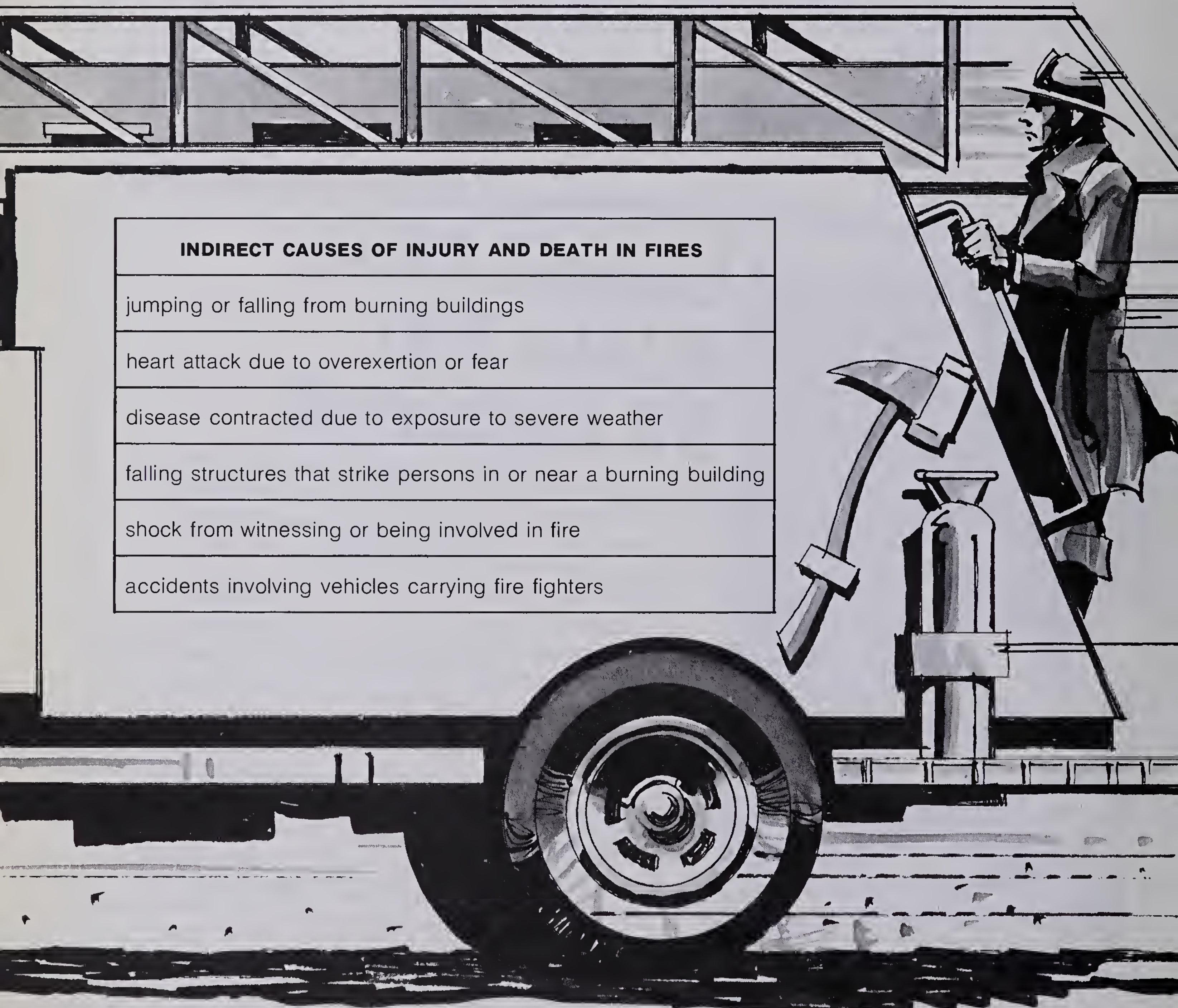
Almost all the customers tried to leave by the front door—the only exit they were familiar with. Their crowding led to what some survivors called a "frantic, bitter struggle" in which those weakened and choked by smoke fell to the floor and were trampled to death by the panicked mob.

Figure 7–2

• 7–4. According to the news story in Figure 7–2, there were four different causes of death. Name the causes and tell whether each one was a direct or indirect result of the fire.

7-4. *Direct causes:* flames, smoke, lack of oxygen; *indirect cause:* trampling.

Panic during fire is a major cause of injury and death. Panic leads to crowding and trampling, which costs many persons their lives. These deaths are *indirectly* caused by fires. Figure 7–3 shows some other indirect causes of death and injury in fires.



INDIRECT CAUSES OF INJURY AND DEATH IN FIRES
jumping or falling from burning buildings
heart attack due to overexertion or fear
disease contracted due to exposure to severe weather
falling structures that strike persons in or near a burning building
shock from witnessing or being involved in fire
accidents involving vehicles carrying fire fighters

Figure 7–3

7-5. Answers will vary. Possible answers are: electrocution from fallen wires, injury from fire hoses, explosions within the building.

• 7 –5. Name causes of death or injury other than those listed in Figure 7–3 that might be indirectly related to fires.

Smoke — A Quiet Killer

Smoke is a major hazard in a fire. Inhaled smoke can lead to asphyxiation. To find out how often asphyxiation actually occurs, do the following investigation. You can do the investigation at home or in your school library.

Find and read newspaper articles about fires that have occurred in your area or in a large city nearby. Record the following information:

1. The total number of casualties (injuries and deaths) that were reported.
2. The number of casualties that were caused by smoke.
3. The percentage of fire casualties that resulted from smoke.

$$\text{percentage } (\%) = \frac{\text{casualties caused by smoke}}{\text{total casualties}} \times 100$$

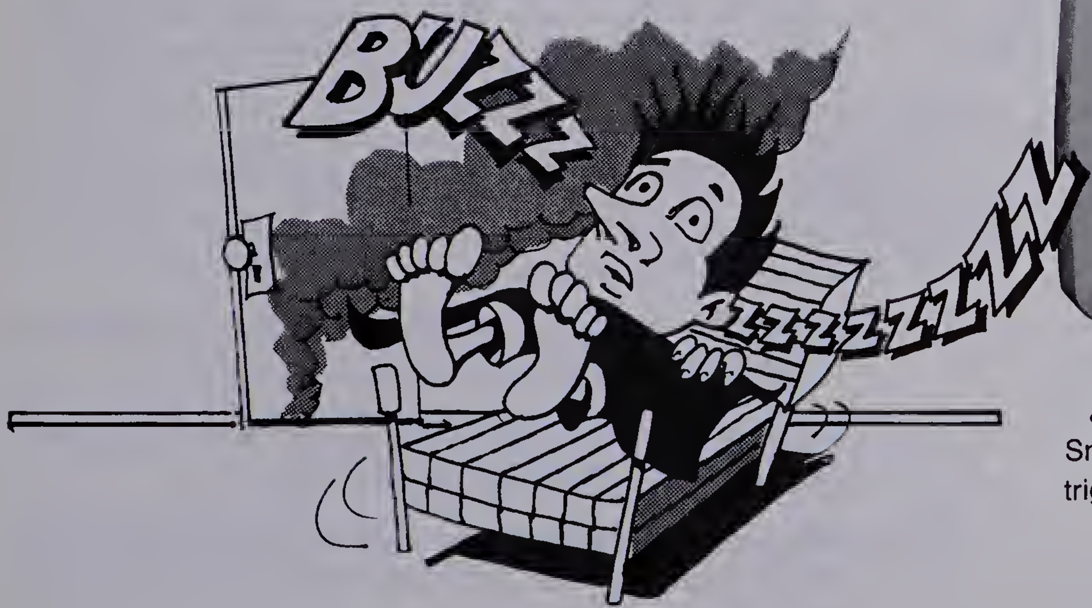
Report your results to your teacher. See how they compare with other reported results.

• 7 –6. For each fire you collected data on, what percentage of the casualties resulted from smoke?

7-6. Answers will vary.

Smoke and other gases usually travel faster than flames. These gases may overcome sleeping persons long before flames or heat are detected.

Many public buildings, newer homes, and mobile homes have special fire detectors. In the presence of smoke or high temperatures, the detectors trigger an alarm. Usually the alarm is a loud buzzer. This is especially useful for alerting sleeping people to a fire.



Smoke or high temperatures trigger this UL-listed alarm.

Fire and smoke detectors must be effective. There are nationally recognized laboratories that test the effectiveness of detectors and other products. Two such laboratories are the *Underwriters Laboratories (UL)* and the *Factory Mutual System.*

- 7–7. Should you expect flames from a fire to awaken you in time to escape? Explain.

Would you know what to do if you were in a burning building? There's some good advice in the Ann Landers column shown in Figure 7–4. Read the advice and then answer Questions 7–8 through 7–13.

In event of fire... know these helpful suggestions

Dear Ann Landers: How would you like to save some lives today?

Millions of people read your column. Please print these suggestions on what to do in case of fire. Ask your readers to post them somewhere in the house for all to see. Taping them to the refrigerator is a good idea.

I read these suggestions in Look magazine in 1971. I then had them retyped when the article became too ragged to read. Now I'd like to clip it from Ann Landers' column and post it again. How about it?
Faithful Fan.

Dear Fan: Here it is. Start clipping. And thank you in behalf of those whose lives may be saved because you took the time and trouble to write.

1. When a fire breaks out in your home or office, get out immediately. A fire can spread faster than you can run. Even if you smell smoke, get out.

2. If you find smoke in an open stairway or hall, use another pre-planned way out.

3. If you escape through smoke, stay near the floor where the air is better. Take short breaths. Breathe through your nose, and crawl to an exit.

4. Make sure your family knows the quickest and safest ways to escape from every room in the house. Keep a flashlight in all rooms to help escape at night. Make sure children can open doors, windows and screens to the escape routes. Teach your children how to use the phone to report a fire. And they should know where the alarm box is in the neighborhood.

5. Head for stairs—not the elevator. A bad fire can cut off the power to elevators. An elevator could also deliver you to the fire floor.

6. Don't jump. Many people have jumped and died without realizing rescue was only a few minutes away.

7. If you are trapped in a smoke-filled room, stay near the floor where the air is better. If possible, sit by a window where you can call for help. Open it at the top and bottom. Heat and smoke will go out the top. You can breathe at the bottom.

8. Feel every door with your hand. If it's hot, don't open it. If it's cool, make this test: open slowly and stay behind the door. If you feel heat or pressure coming through the open door, slam it shut.

9. If you can't get out, stay behind a closed door. Any door will serve as a shield.

10. If there is a panic for the main exit, get away from the mob. Try to find another way out. Once you are safely out, don't go back in. Call the fire department. Use alarm box or telephone. In the country, be sure you know the number of the closest volunteer fire department. Never assume someone else has turned in the alarm.

Figure 7–4

7-7. No. Smoke and dangerous gases can get to you before the flames do. These gases will "keep you unconscious," making escape impossible.

7-8. Get out immediately.

7-9. Try to find an alternate exit. Crawl on the floor and take short breaths through your nose.

★ **7–8. What's the first thing you should do if a fire breaks out in the building that you're in?**

★ **7–9. Suppose smoke is blocking your escape from a burning building. What should you do?**

★ **7–10. Suppose you're trying to leave a burning building. How should you test the doors that you have to use to escape?**

7-10. Feel the door with your hand to find out if the door is hot. If it's not hot, open the door slowly, staying behind it.

• 7–11. When there's a fire, who should call the fire department?

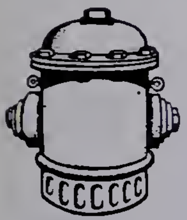
★ 7–12. What should you do if you're trapped in a burning house and there's no way to get out?

• 7–13. What is the telephone number to use for reporting a fire in your home? In your school? Where can you find these numbers if you forget them?

7-11. You! Never assume that someone has already made the call.

7-12. Close the door, stay near the floor by a window. Open the window from the top and the bottom.

7-13. Answers will vary, but students should give the number of the fire department or the emergency number for the town. The numbers can be found in the phone book (usually in the front) and should be displayed near or on each phone.



Activity 8
Boom!

ACTIVITY EMPHASIS: The conditions necessary for an explosion to occur; conditions that increase the danger of explosions occurring.

MATERIALS PER LAB GROUP
See Materials and Equipment, pp. TM 3-6.
See also Advance Preparation, pp. TM 7-9.

In this activity, you'll investigate different kinds of explosions. For the first explosion, you'll need a small paper or plastic bag.

CAUTION	**Warn your neighbors to protect their ears.**

You may want students to pop the bags away from other students to avoid startling them.

A. Blow as much air into the bag as you can. Then with one hand, hold the top of the bag *very tightly* closed to trap the air inside. Keep the bag away from your face and ears, and away from other persons.

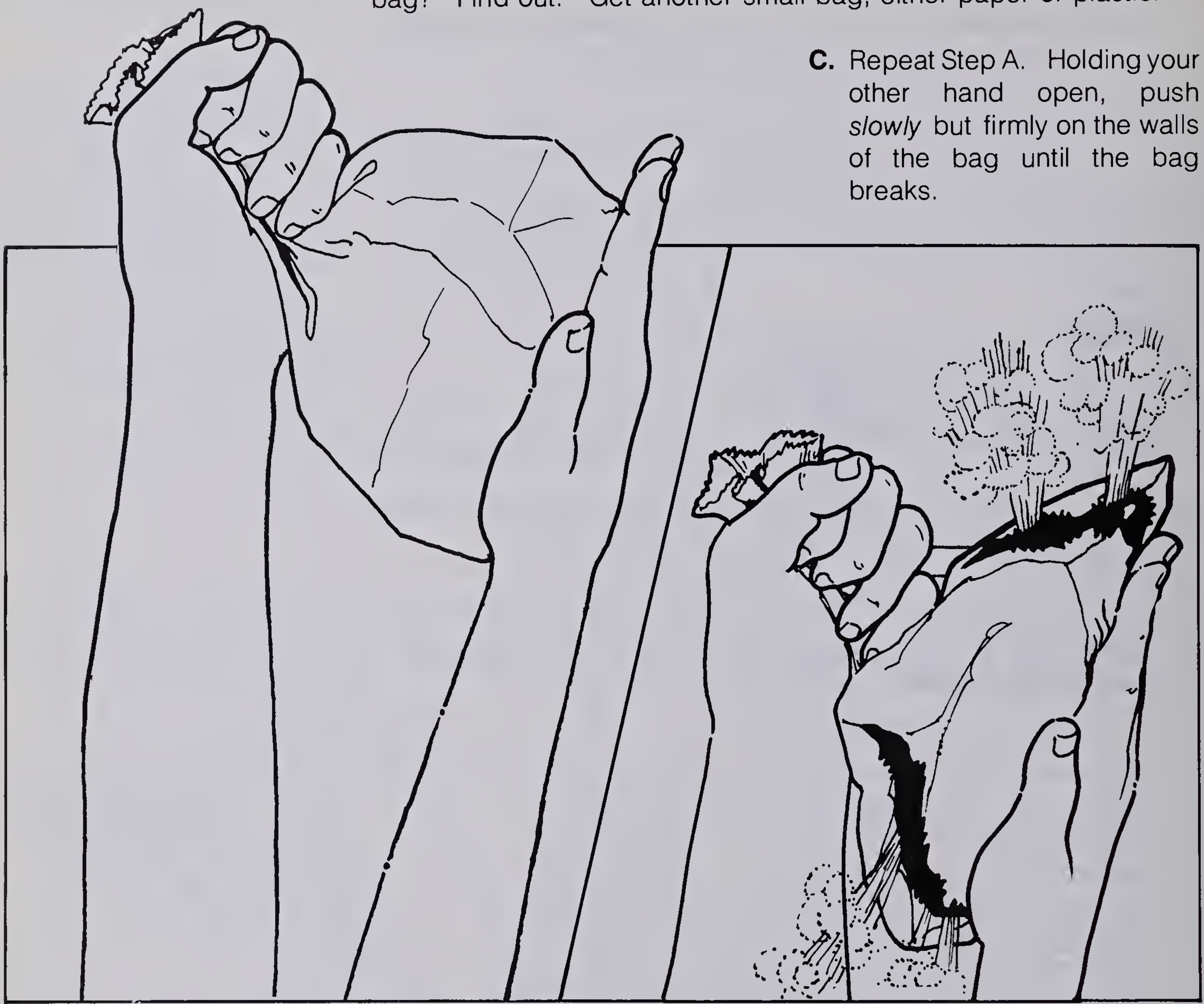
B. Holding your other hand open, hit the bag *quickly* with a very hard blow.

Was there a loud noise and did the bag split open? If not, try it again. If so, then you just witnessed a safe explosion.

What made this an explosion? There was gas trapped in the bag. The blow of your hand on the bag caused a very fast buildup in gas pressure. The bag couldn't take all the pressure. It suddenly ripped open, releasing the gas. The sudden release of gas caused a shock wave in the surrounding air. The shock wave caused the noise you heard.

What happens when you *slowly* push your hand against an air-filled bag? Find out. Get another small bag, either paper or plastic.

C. Repeat Step A. Holding your other hand open, push *slowly* but firmly on the walls of the bag until the bag breaks.



When you pushed slowly against the air-filled bag, there was a much slower buildup of pressure. Probably the bag tore open, but without a loud noise.

8-1. The slower the speed of the pressure buildup in the bag, the less likely an explosion will occur.

- 8 –1. How does the speed of pressure buildup inside a paper or plastic bag affect whether there's an explosion with a loud noise or just a tear in the bag?

The exploding bag has one thing in common with all explosions that result from burning (ignition) — a very rapid buildup of gas pressure. All ignition explosions are the result of a rapid buildup of gas pressure.

You've probably seen explosions on television or in the movies. If you looked closely, you saw materials breaking up and rapidly moving away from the point of the explosion. Figure 8–1 shows the result of a rapid buildup of pressure in an explosion.

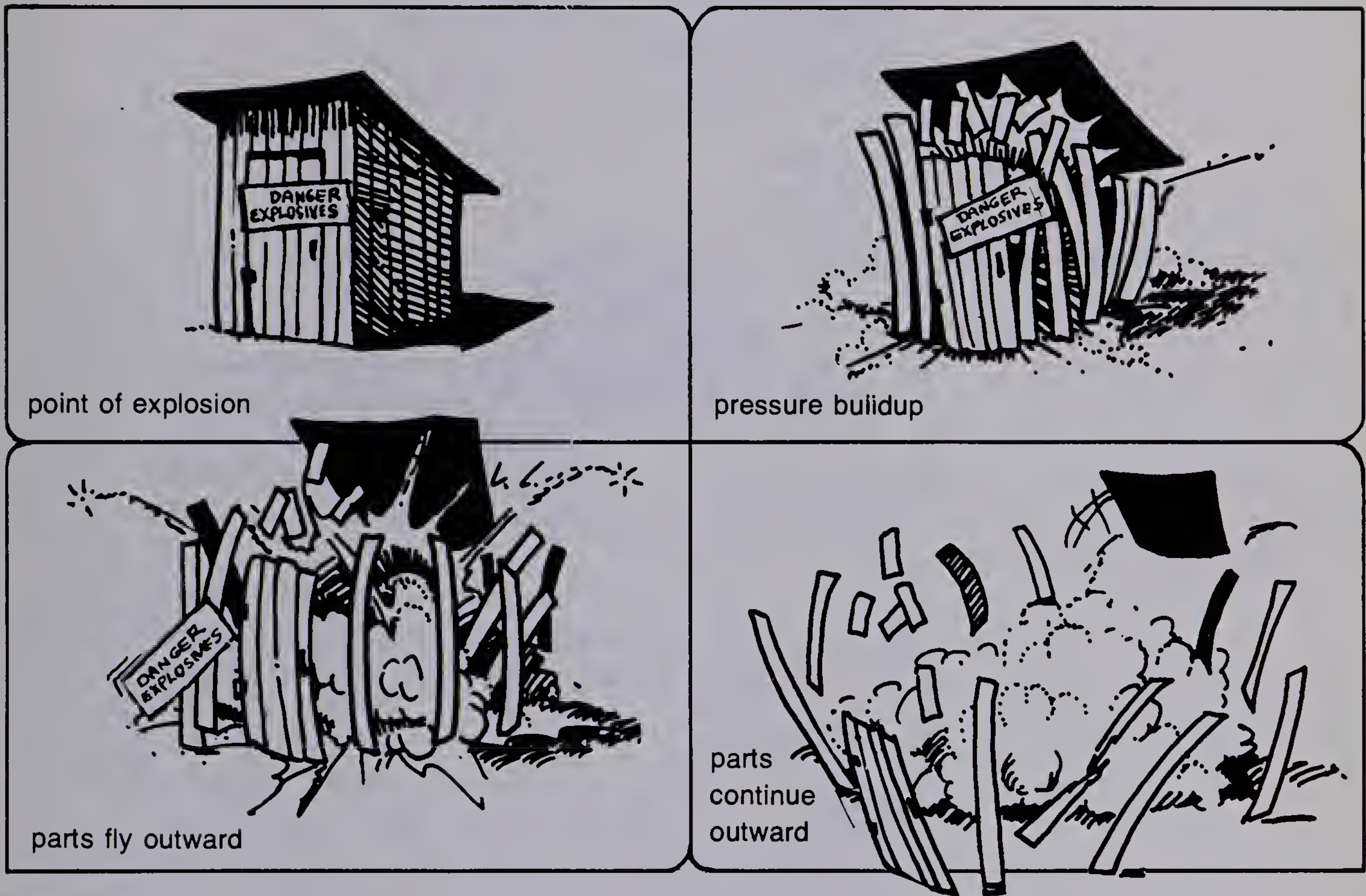


Figure 8–1

In Figure 8–1, there was an explosive substance in the small shed. This explosive substance suddenly ignited and changed to a gas producing high pressure. The very fast increase in gas pressure exerted great force against the walls and roof of the shed. This sudden force blew the shed apart.

★ 8–2. What condition do all ignition explosions have in common?

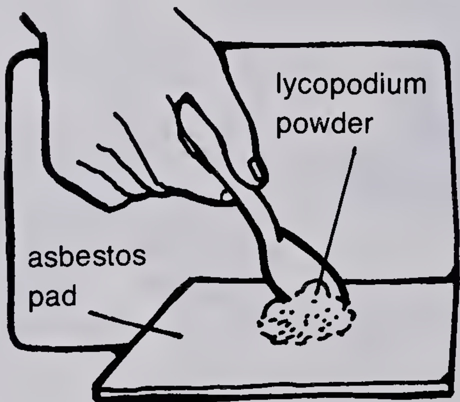
8-2. A very rapid buildup of gas pressure.

Explosions can result from gas formation during very rapid burning. You can produce such a reaction yourself. The reaction will be done without a container to avoid the danger of flying pieces of broken container. So the reaction will be a safe "mini" boom, not a dangerous explosion.

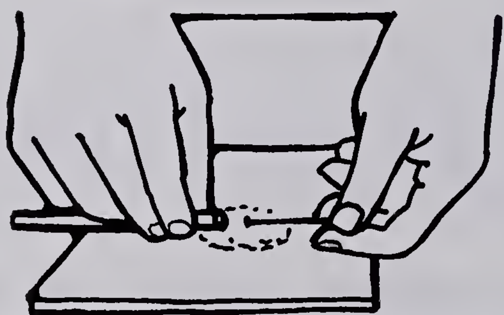
You'll need to use a Bunsen burner in this investigation. If you don't know how to use one, do *Resource Unit 17*. Then do the investigation. It will take about 10 minutes. You'll need the following items:

safety goggles
teaspoon
lycopodium powder
asbestos pad
nail
soda straw
paper towel
Bunsen burner
matches

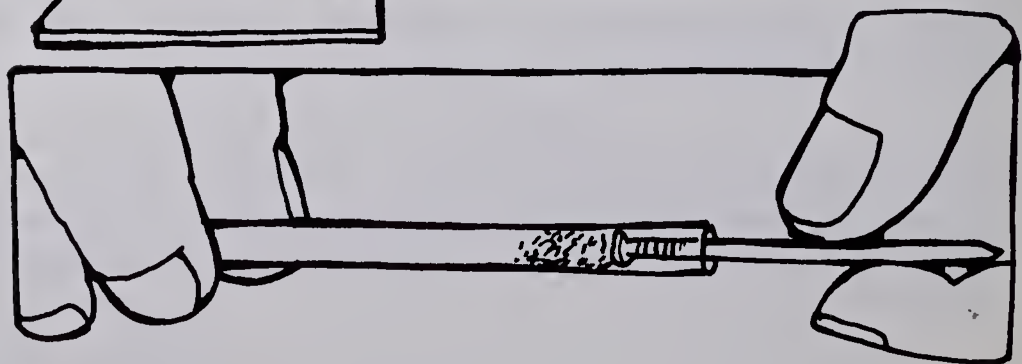
IMPORTANT **This investigation must be done in a special protected area of the room. If you don't know where the area is, ask your teacher.**



A. Put a spoonful of lycopodium powder on the asbestos pad. With the head of a nail, push some powder into one end of the soda straw. Fill about 2 cm of the straw with powder.

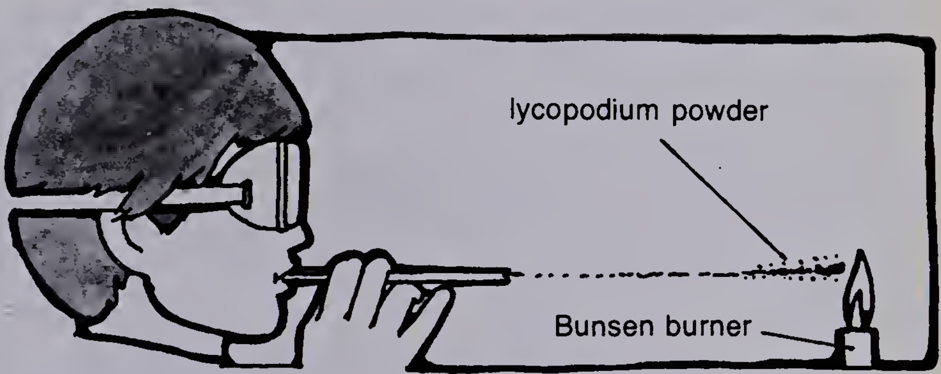


B. Using the head of the nail, push the column of powder farther into the straw so that it is about 2 cm from the end of the straw. With the paper towel, gently wipe off any powder sticking to the outside of the straw. Put the straw aside. Don't spill the powder!



CAUTION **Before doing Step C, be sure that there's no one near the burner and that all flammable items have been removed. Also, in Step C, breathe only through your nose when the straw is in your mouth. Be sure to wear your safety goggles.**

C. Light the burner. Gently lift the straw and put the end *without* the powder into your mouth. Then, *keeping your face at least 50 cm from the flame,* blow the powder into the flame. Observe what happens. Turn off the burner.



• 8–3. Describe what happened when you blew the powder into the flame of the burner. Explain why it happened.

8-3. Answers will vary, but a "poof" sound and a flash of light should have been observed. The burning of the powder caused a rapid buildup of pressure in the air around the fire.

Remember, explosions from burning occur when there's a very rapid buildup of gas pressure. You caused an ignition explosion when you blew powder into the flame. The powder ignited and instantly produced lots of gas. The gas pushed outward against the surrounding air. This sent a shock wave to your ears and you heard *poof.*

★ **8–4. Suppose a powder was ignited within a closed container and lots of gas was produced. Predict what would happen to the gas pressure inside the container. Predict what might happen to the container.**

8-4. There could be a very rapid buildup of pressure inside the container, causing the container to explode.

When substances burn, atoms are rearranged rapidly to form gases. Usually heat is given off. For some chemicals, the volume of gas produced is tremendous compared to the volume occupied by the starting materials. That is why there is a sudden and tremendous buildup of pressure. Anything near such a reaction will feel the effects of the heat energy and pressure.

• 8–5. Explain why it is dangerous to mix chemicals when you have no idea whether they may react rapidly to form gases.

8-5. An explosion could occur.

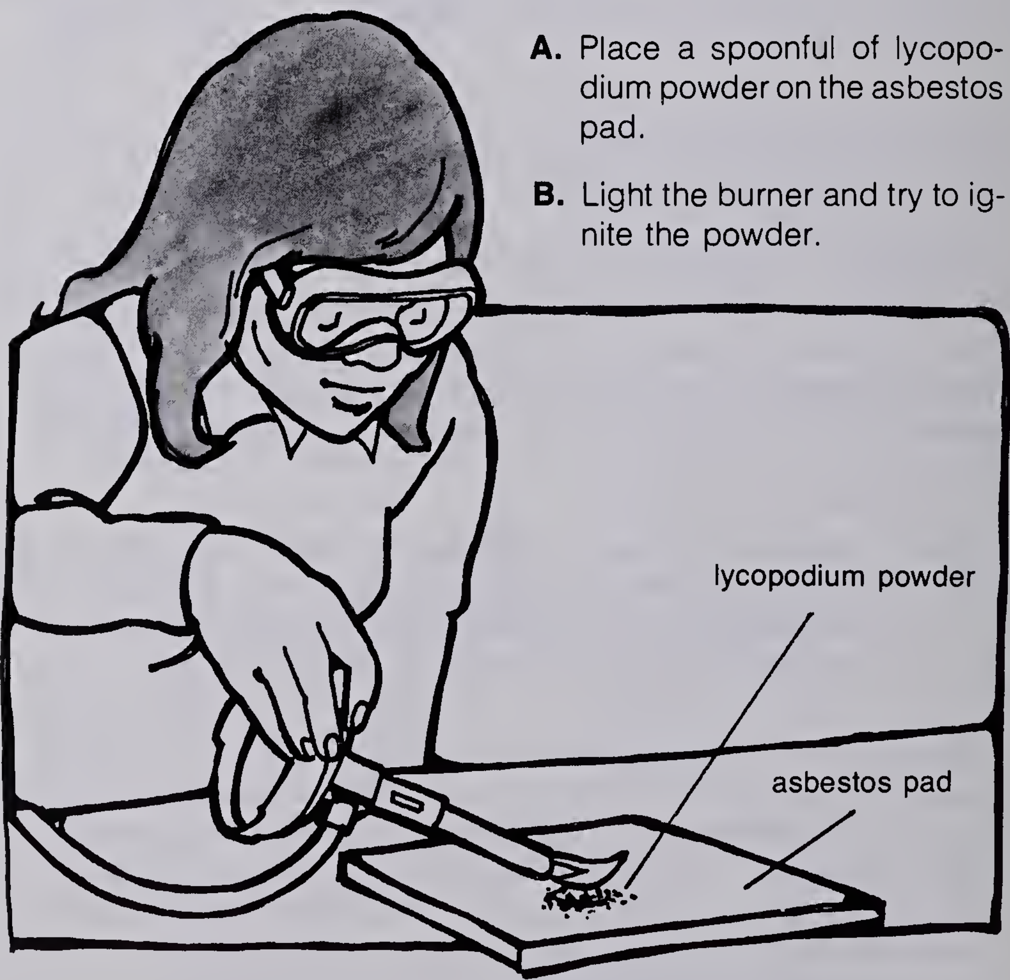
Things that in one situation burn rather slowly can also burn explosively. Remember what happened to the lycopodium powder when it was blown into a flame? This powdered fuel burned explosively. What if all the powder had been together in a pile? Would it have burned explosively? Find out. The investigation will take about 5 minutes to do. Get the following items:

safety goggles
lycopodium powder
teaspoon
asbestos pad
Bunsen burner
matches

CAUTION **Use a Bunsen burner, *not* an alcohol burner, for this investigation.**

A. Place a spoonful of lycopodium powder on the asbestos pad.

B. Light the burner and try to ignite the powder.



8-6. Some scorching took place, but the powder did not burn.

• 8–6. Describe what you observed when you tried to burn the powder.

In finely powdered fuel, or *dust*, all the individual particles can reach their ignition point more quickly than in a pile of powder. Also, there is more space between the particles in the dust. So oxygen can get close to each particle. Thus, fine powder ignites and burns more easily and quickly than when packed in a pile.

In flour mills, there is always the danger of a flour-dust explosion. And in other industries, combustible dust that's produced — such as wood dust or cloth fibers — can explode if a spark reaches the dust particles. Dust explosions occur frequently. Stories like the one shown in Figure 8–2 often appear in newspapers.

EXPLOSION AT LOCAL PLANT

An explosion today at the particle board plant killed one person and injured several others. The man who was killed was operating the wood-grinding machine when it exploded.

The explosion blew a large metal door off the grinding machine and also blew off the outside door to the factory.

An eyewitness said the explosion made a noise like a dynamite blast and produced a ball of flame about twenty feet in diameter. Several small fires were started by these flames.

The owner of the factory said a spark apparently ignited wood dust inside the wood-grinding machine. A device on the grinder which is supposed to prevent such sparks from occurring apparently failed to operate.

Figure 8-2

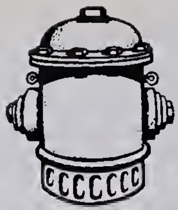
★ **8–7. Why is finely ground fuel-dust that's blown into the air likely to be more explosive than a chunk of fuel?**

8-7. Air and heat energy can get to the fuel particles more quickly, thus producing rapid and complete ignition.

★ **8–8. In your notebook, supply the missing information for *a-f*. An explosion is a *rapid* ignition of *(a)*. This ignition produces *(b)* and *(c)*. A rapid buildup of *(d)* occurs that can cause a container (if there is one) to *(e)*. A shock wave may also result, causing a *(f)*.**

8-8. (a) fuel; (b) heat energy or gas; (c) gas or heat energy; (d) pressure; (e) explode, break apart, etc.; (f) noise, loud noise, etc.

MATERIALS PER LAB GROUP
See Materials and Equipment, pp. TM 3-6.
See also Advance Preparation, p. TM 9.



ACTIVITY EMPHASIS: Potentially hazardous situations for fire and explosions. Deciding why the situations are hazardous, and a home/school survey of safe and unsafe conditions.

Activity 9
For Safety's Sake

The *Hazard Checklist*, supplied separately, is needed for this activity. Be sure to have enough copies available.

How well can you detect fire hazards? Carefully examine each of the hazard-situations shown in Figure 9–1. Then answer Questions 9–1 through 9–4.

FIRE HAZARDS

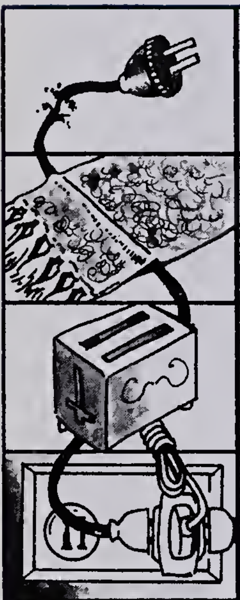
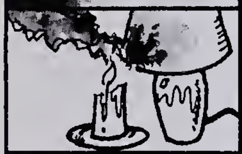
	1. Electrical sparks or heat from frayed electrical cords can set nearby substances on fire.		10. Don't use flammable liquids near flames or high temperatures—the fumes may ignite and explode.
	2. Electrical cords under rugs or over doorways or nails can fray, short circuit, and start a fire.		11. Use flammable liquids in well-ventilated areas so that fumes won't build up and explode.
	3. Heat sources too near electrical cords can burn or melt insulation on the cord and then start a fire.		12. Keep containers for flammable liquids in an airy spot away from children. Flammable liquids are poisonous.
	4. Too many plugs in one outlet can cause the wires to heat up and set fire to material inside the walls.		13. Store only small amounts of flammable liquids in closed metal or special plastic containers.
	5. Paper, cloth, and other cumbustibles should not be placed near heat sources—fire may result.		14. Store oily rags in closed metal containers away from heat sources or flammable liquids.
	6. A higher-wattage bulb than recommended can give off enough heat to burn the lamp shade.		15. Let gasoline engines cool before adding gas. Don't use gas to start fires—the fumes could explode.
	7. Put matches out of reach of children who could accidentally start a fire.		16. Never add starter fluid to hot coals—the flames can travel up the stream to the container, causing an explosion.
	8. Never smoke in bed. A lit cigarette and a sleeping person could mean disaster!		17. A metal fire screen should be used with a fireplace. Hot sparks could fly and set fire to nearby substances.
	9. Let ashes cool overnight before disposal into metal containers. Position cigarettes to fall into ashtrays.		18. Flammable liquids should not be used to clean hands—the fumes may irritate the skin or may ignite.

Figure 9–1

9-1. Children might get hold of them and accidentally start a fire.

★ **9–1. What danger could exist by keeping matches handy, in easy-to-reach places?**

• 9 –2. Why is it dangerous to place electrical cords out of sight under rugs or carpets?

• 9 –3. Why is it dangerous to pour starter fluid on burning coals?

★ **9–4. Why is it dangerous to use flammable liquids near (but not really touching) a flame or heat source?**

Did you ever hear the saying, "An ounce of prevention is worth a pound of cure"? Apply the saying to fires and explosions. That is, check your home for all the things that could cause a fire or explosion. Become a *home fire marshal* for a day!

Get a *Hazard Checklist*. If there's none available, ask your teacher for one. Use the *Hazard Checklist* and Figure 9–1 to check your home for potential fire or explosion hazards. Analyzing your home might take a short time, or you might want to make a project out of it.

• 9 –5. Name the fire hazards that you found in your home.

• 9 –6. What would you do to eliminate each hazard you found in your home?

• 9 –7. Suppose you found hazards that were caused by people doing something potentially dangerous. Would you try to correct their behavior, or would you hesitate? Explain.

★ **9–8. Look at Figure 9–2. Tell whether each situation (a-d) is safe or unsafe.**

9-2. They could become frayed, develop a short circuit, and start a fire.

9-3. Flames could travel up the stream to the container, which may explode.

9-4. Fumes (gases) are often present and can explode.

9-5. Answers will vary.

9-6. Answers depend on the answers to Question 9-5.

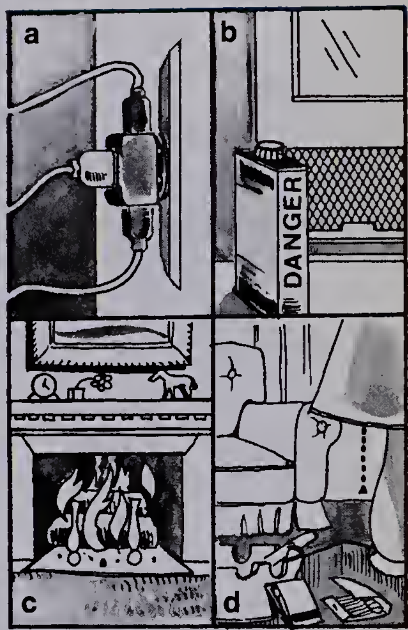
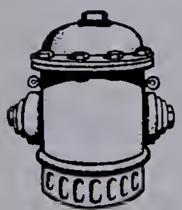


Figure 9–2

9-7. Answers will vary, but a person's obligation to another should not be put aside because of fear or embarrassment.

9-8. *Unsafe:* a, c, d; *Safe:* b



Activity 10
Just in Case!

Whether you live in a house, an apartment, a mobile home, or a houseboat, you need to know how to get out in case of fire. A fire is an emergency. And it's easy to panic and make mistakes in emergencies. The only way to prevent panic is by planning ahead. In this activity, you'll plan how to escape in case of fire.

ACTIVITY EMPHASIS: This is a required activity. Students plan and execute an escape plan for each bedroom in their homes.

MATERIALS PER LAB GROUP
See Materials and Equipment, pp. TM 3-6.

Find Two Escape Routes

Most home fires that cause death start while people are asleep. Often the usual exits (doors, stairs) are blocked with smoke or heat. Thus, it's a good idea to have two escape routes from each bedroom. Then if the usual exit is cut off by fire or smoke, the other route can be used.

10-1. Answers will vary.

- 10 –1. How many bedrooms does your home have?

10-2. Answers will vary.

- 10 –2. For each bedroom in your home, draw an *Escape Floor Plan*. (Follow the steps in Figure 10–1.) Use a small piece of paper or index card for each floor plan.

STEP 1

Make an outline (floor plan) of each bedroom
(drawings need not be exact).
Show the windows,
bed, and door (normal escape).
Select the best window
(or other way) for an
emergency escape.

STEP 2

Complete the Escape Floor Plan.

① Show the *normal* escape.

② Show an *emergency* escape.

Figure 10–1

Show your *Escape Floor Plans* to your teacher. Then be sure to display each plan in the appropriate bedroom. The plans must be placed in conspicuous places — where they can always be seen.

The second escape route (the emergency one) may require some special preparations. For instance, if the route includes an upstairs window, you may have to supply a window escape ladder. And there may be things that must be done to the window. If the window is kept locked, make sure everyone knows how to unlock it. Decide what to do about storm windows and screens.

In planning escape routes, you must plan for special help for infants or other people who cannot move quickly by themselves. Sometimes a special escape route must be planned for these people.

If in doubt about any item of your plan, ask someone in the local fire department for advice.

Family Discussion of Escape Plans

After you plan the escape routes, your next job is to discuss some escape plans with your family. As a guide for the discussion, use the *Family Escape Instructions* in Figure 10–2. After your discussion, answer Questions 10–3 through 10–5 (page 48).

FAMILY ESCAPE INSTRUCTIONS

1. Keep bedroom doors *closed* at night. A door can hold back deadly smoke, heat, and gases until you can use your emergency escape. This door can be a lifesaver!

2. Agree how to *wake up* all the family in case fire cuts off your doorway. Consider pounding on walls or ceiling, hollering, using a whistle, etc.

If you have an automatic fire-detection alarm system for the home, it can give an early warning. Only use an alarm system that shows the seal of a nationally recognized testing organization, such as UL or FM.

3. *Don't waste time* getting valuables, getting dressed, or fighting the fire. Get everyone out!

4. *Test doors* before opening them. First, check to see if the door is hot, or if smoke is leaking in at the edges of the door. If so, don't open it. Use your emergency route! If you think it's safe, open the door cautiously, staying behind it. Brace yourself against the door. Be ready to slam it shut if heat rushes in.

5. Agree on an *outside meeting place* to check if everyone is safe. Once out, stay out!

6. Call the *fire department* quickly, from a street alarm box or a neighbor's phone. (Don't go back into your house to use your phone.)

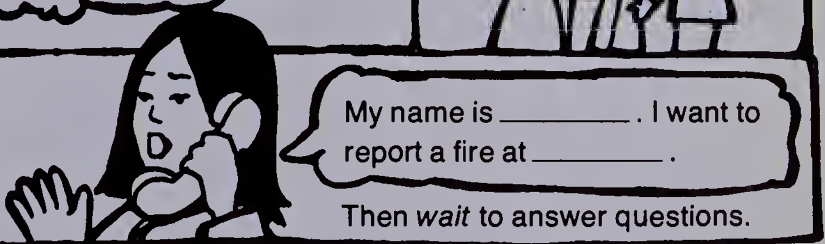


Figure 10–2

10-3. Answers will vary, but one possibility is pounding on the wall.

10-4. Answers will vary, but the place should be far enough away from the fire.

10-5. Answers will vary, but if there is no close alarm box, a phone call would be best.

- 10 –3. What signal will your family use if there's a fire at home?

- 10 –4. Exactly where will your family gather outside?

- 10 –5. Where is the closest fire alarm box to your home? If there is no fire alarm box nearby, how will you turn in the alarm?

Practice Fire Drill

After your escape plan has been made and discussed with your family, there's one more important thing to do. Practice the plan! If a fire occurs at night, everyone must react quickly, correctly, and automatically. There should be no panic. Now practice your fire drill with your family. Go through the drill at least twice. Use both the regular escape route and the emergency escape route.

Figure 10–3 shows the four steps of a good fire drill. Practice the steps!

FIRE DRILL!

Alert your neighbors that you're having a drill. Fire drills make you practice using escape routes.

Then, in a fire crisis, each person acts correctly. (There are no panic mistakes.)

Have an Escape Floor Plan for each bedroom (2 exits).

NOW PRACTICE—

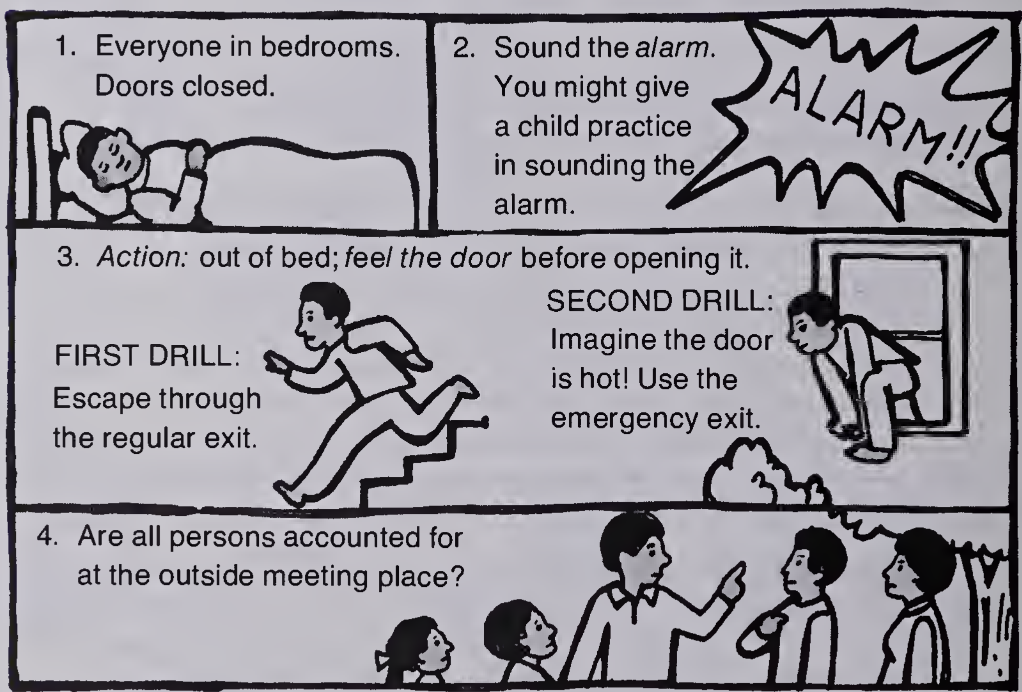


Figure 10–3

10-6. Answers will vary, but the best argument is, "I'm trying to save your lives because I love you."

10-7. Yes, there's usually a plan. It's posted in a conspicuous place, most times near the classroom door, clock, or chalkboard.

- 10 –6. Most people are embarrassed to do fire drills in their own homes. Describe how you helped your family overcome embarrassment to practice the fire drill.

- 10 –7. Schools have regular fire drills. How do you know where to go when the fire alarm rings? Is there a plan?

Activity 11
Advanced Planning

Activity 12 Page 50

Objective 12-1: Explain why burning is classified as an oxidation-reduction reaction.

Sample Question: What happens when a burning reaction occurs?

a. One kind of atom gains electrons and another kind loses electrons.
b. Oxygen atoms lose electrons.
c. There are fewer electrons in the products of burning than in the substances that burned.

Activity 13 Page 53

Objective 13-1: Describe the effect on the products of a burning reaction when the amount of fuel or oxygen is varied.

Sample Question: During burning, what happens if there is not quite enough oxygen present in the air to cause complete combustion of a substance containing carbon?

a. The flames go out immediately.
b. CO is formed in addition to CO_2.
c. More heat energy and less light energy are produced.

Objective 13-2: Design and carry out an experiment that tests what effect varying the amount of oxygen or fuel has on the products of a burning reaction.

Sample Question: Write an hypothesis for an experiment designed to test what effects there would be on the products of the burning fuel (methane) of a Bunsen burner if the amount of oxygen entering the burner was varied.

Activity 14 Page 59

Objective 14-1: Explain what activation energy is, how it is related to other energy changes in a burning reaction, and how it is affected by a catalyst.

Sample Question: What is the activation energy of any burning reaction?

a. the amount of energy needed to break chemical bonds in the fuel and oxygen
b. the amount of heat energy released as a substance burns
c. the chemical-bond energy of substances produced in a burning reaction

Answers
12-1. a 13-1. b 13-2. See your teacher
14-1. a

ACTIVITY EMPHASIS: Burning as one type of oxidation-reduction reaction. Oxidation-reduction is discussed as electron transfer; a periodic table acts as a guide for deciding relative "electron greediness."

MATERIALS PER LAB GROUP
None.

12-1. Oxidation is the losing of electrons; reduction is the gaining of electrons.

Activity 12
Redox

There are different ways that atoms can combine in chemical reactions. Burning reactions are examples of *oxidation-reduction* reactions. The term *redox* [REE-docks] is a nickname for *red*uction-*ox*idation reactions.

If you don't know about oxidation and reduction, look them up in the index of the minicourse *Actions and Reactions*.

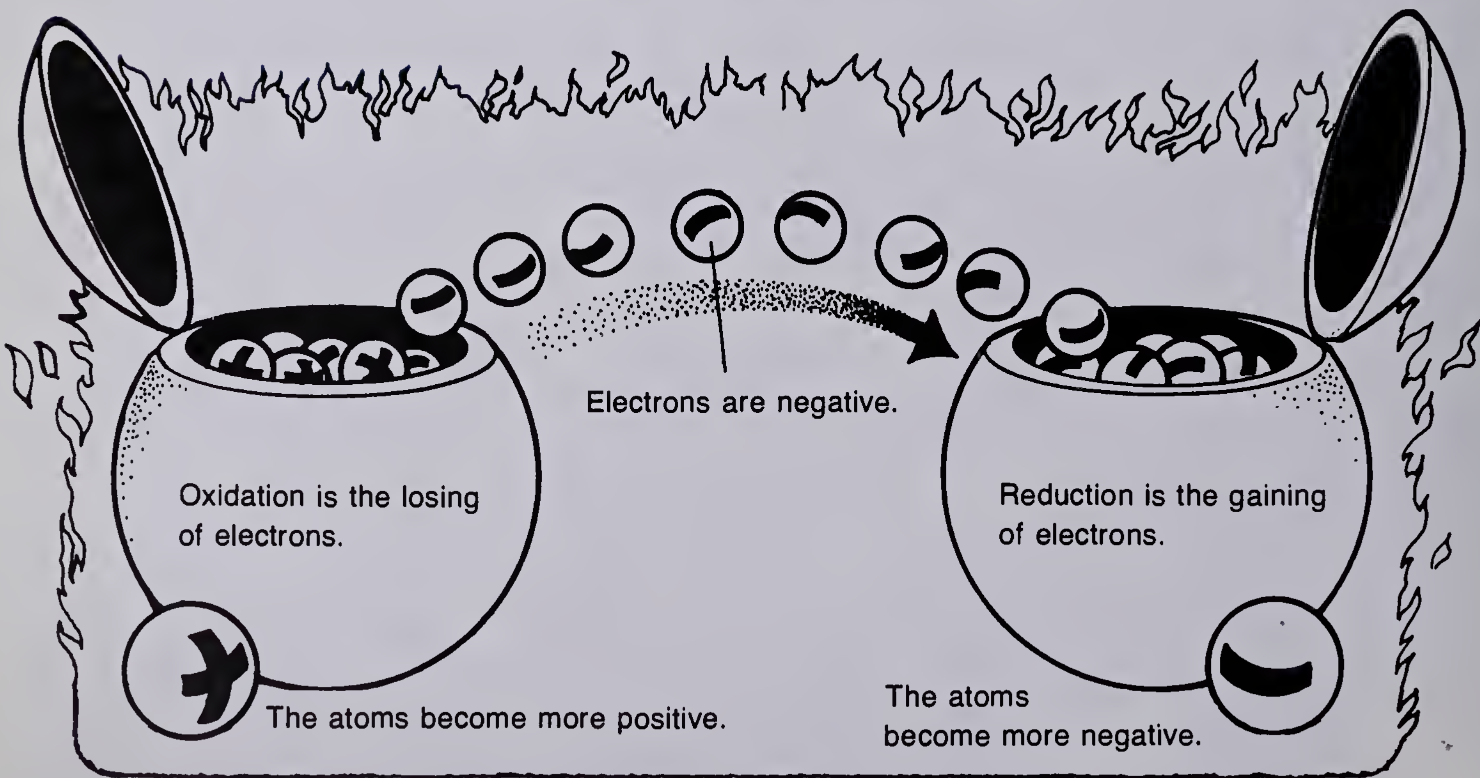
• 12 –1. What is oxidation? What is reduction?

In most fires, two things are occurring at the same time.

Hydrogen and oxygen are combining, producing water and energy (heat and light).

Carbon and oxygen are combining, producing carbon dioxide and energy (heat and light).

One of the things that happens during these combinations is a give-and-take of electrons between atoms.



In a particular reaction, some atoms are electron "givers" and some atoms are electron "takers." This gaining and losing of electrons sometimes depends on unequal electron-sharing between atoms. One atom "takes" more than its share of the shared electrons; the other atom "gives up" more than its share of the shared electrons. Here is a handy rule to remember in deciding which atoms are most likely to *gain* electrons:

Rule: Fluorine is the greediest element of all for taking electrons from other atoms. Find where F (fluorine) appears in the periodic table shown in Figure 12–1. An element that's far from F in the periodic table is less greedy for electrons than an element that's close to F.

- 12 –2. Which elements are closest to F in the periodic table? 12-2. O, S, Cl, Ar, Ne, He

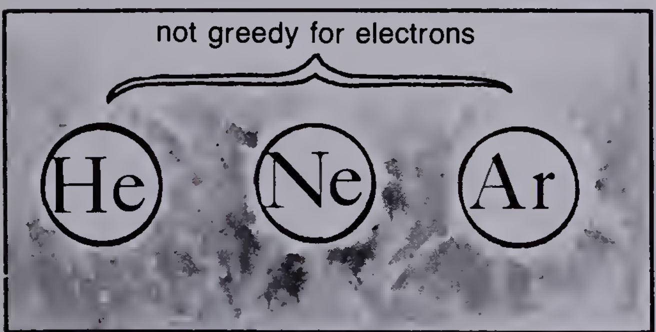
A PERIODIC TABLE OF THE ELEMENTS

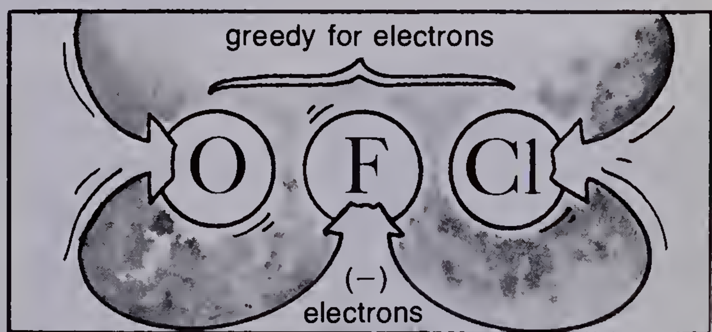
H																															He
Li	Be																									*B	C	N	O	F	Ne
Na	Mg																									Al	Si	P	S	Cl	Ar
K	Ca	Sc															Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y															Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr															

*All elements right of dark line are nonmetals.

Figure 12–1

The elements He, Ne, and Ar don't react with much of anything. But the elements O, S, and Cl are a different story. Each one is greedy for electrons. Next to F, the greediest electron gainers are oxygen and chlorine.





- 12 –3. Where is hydrogen, H, located in the periodic table (*close to* or *far from* fluorine)? 12-3. Far from.

- 12 –4. From its location in the periodic table, would you expect hydrogen to be greedy for electrons? 12-4. No.

12-5. (a) O, (b) H, (c) H is oxidized; O is reduced.

12-6. (a) O, (b) C, (c) C is oxidized; O is reduced.

12-7. (a) O, (b) H and C

12-8. (a) O; it is greedier for electrons than Fe is. (It's closer to F in the periodic table.) (b) Fe

12-9. Fuel atoms give up electrons (oxidation) to oxygen atoms (reduction).

During the redox reactions, atoms that gain electrons are said to be *reduced.* Atoms that lose electrons are said to be *oxidized.* The burning of hydrogen with oxygen is a redox reaction. This reaction is part of practically all fires most people have seen. The following equation shows what happens when hydrogen burns.

$$2H_2 + O_2 \rightarrow 2H_2O + \text{energy}$$

• 12–5. Consider what happens when hydrogen burns.
  a. Which element (H or O) would you expect to take more than its share of electrons?
  b. Which element would you expect to give up some of its share of electrons?
  c. Which element is oxidized? Which element is reduced?

If you are unsure of the answers, refer to the *Rule* on page 51.

The burning of carbon with oxygen is another redox reaction. This reaction is also part of practically every fire. The following equation shows what happens when carbon burns.

$$C + O_2 \rightarrow CO_2 + \text{energy}$$

• 12–6. Consider what happens when carbon burns.
  a. Which element (C or O) would you expect to take more than its share of electrons?
  b. Which element would you expect to give up some of its share of electrons?
  c. Which element is oxidized? Which element is reduced?

If you are unsure of the answers, refer to the *Rule* on page 51.

Redox reactions that produce lots of energy in the form of heat and light are usually called *burning.* These reactions happen rapidly.

• 12–7. Wood is made mostly of carbon and hydrogen. In a campfire, wood reacts with oxygen in a redox reaction.
  a. Which element(s)—C, H, or O—gains electrons?
  b. Which element(s) loses electrons?

★ **12–8. Steel wool is mostly iron, Fe. When steel wool burns, which element (Fe or O) would you expect to**
  a. gain more than its share of electrons and be reduced? Why?
  b. give up more than its share of electrons and be oxidized?

★ **12–9. Explain why burning reactions involving oxygen are called oxidation-reduction reactions.**

Activity 13
Ashes and Gases

ACTIVITY EMPHASIS: The variations in the nature of burning-reaction products when the relative amounts of reactants are varied. Students design an experiment to determine what happens to the products of burning when the reactants are varied.

MATERIALS PER LAB GROUP
See Materials and Equipment, pp. TM 3-6.
See also Advance Preparation, p. TM 9.

The *Burning Experiment Form,* supplied separately, is needed for this activity. Be sure to have enough copies available.

In fires, more injuries and deaths are caused by smoke and gases than by flames. What are these dangerous gases? Are they produced in all burning reactions?

In this activity, you'll investigate some of the gases produced by burning reactions. You'll need to use a Bunsen burner. If you don't remember how to use one, do *Resource Unit 17* now. Then do the investigation. It will take about 20 minutes. Get the following items:

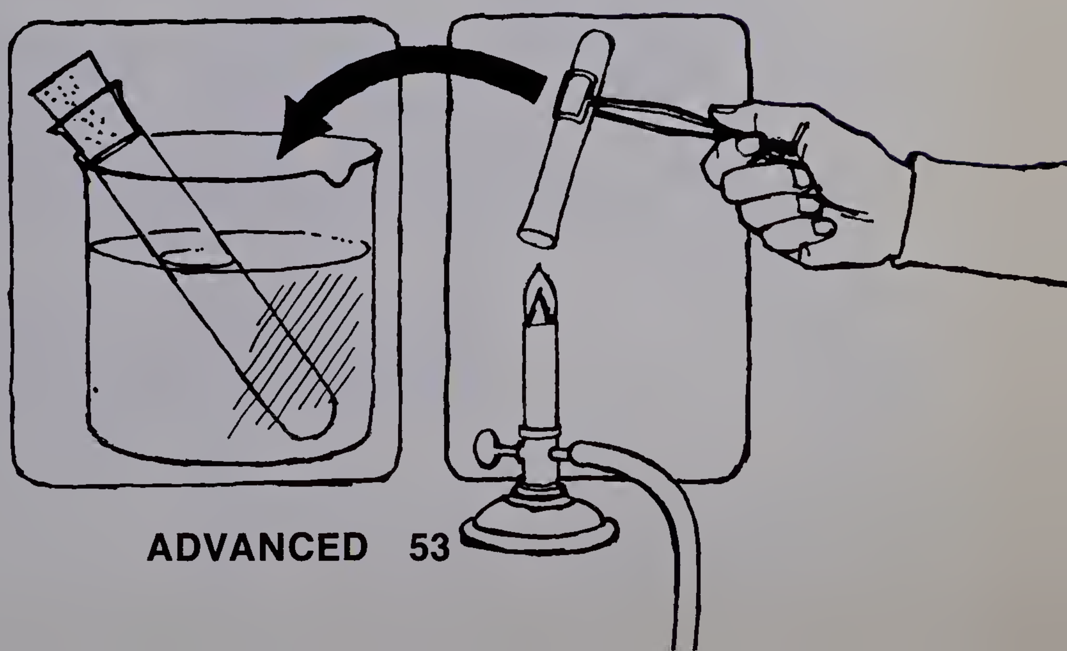
safety goggles
beaker or container
cold water
Bunsen burner
matches
test-tube holder
test tube with stopper
paper towel
graduated cylinder
limewater

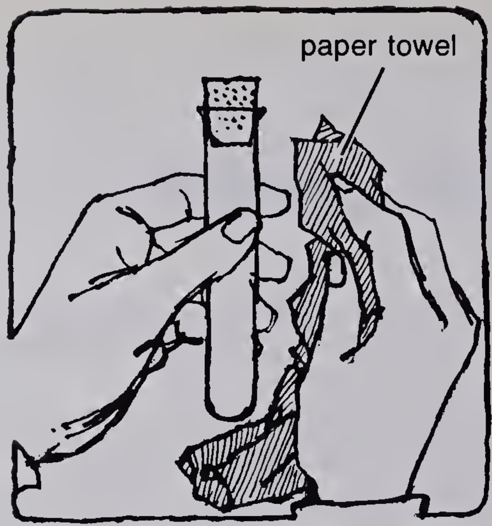
CAUTION

Use a Bunsen burner only. Do not use an alcohol burner.

Be careful when stoppering the test tube in Step A. The tube opening is very hot.

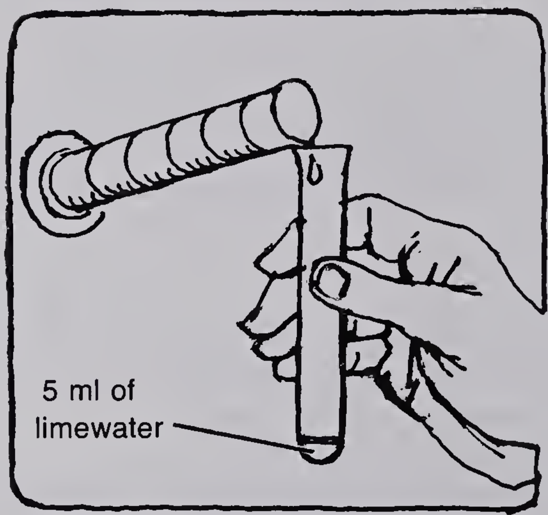
A. Fill the beaker about $^2/_3$ full of cold water. Then light the burner and adjust it for a blue flame. Using the test-tube clamp, hold the open end of the empty test tube over the flame for about *5 seconds*. Then remove the tube from the flame and quickly stopper the tube. Put the test tube in the beaker of cold water. Turn off the burner.





B. When the test tube is cool enough to handle, wipe off all the water from the outside of the tube. Observe the contents of the test tube.

C. Remove the stopper from the test tube. Using a graduated cylinder, quickly add 5 ml of limewater to the test tube. Then restopper the tube. Shake the test tube gently and observe the contents.



13-1. Small droplets of moisture.

- 13–1. In Step B, what did you observe inside the test tube?

13-2. The limewater turned milky or cloudy.

- 13–2. In Step C, what did you observe inside the test tube?

Limewater turns milky when it reacts with carbon dioxide, CO_2.

13-3. Carbon dioxide is present in the test tube.

- 13–3. What conclusion can you make about the presence of carbon dioxide inside the test tube?

The natural gas fuel for a Bunsen burner is mostly methane, CH_4. When there is plenty of oxygen (or air), methane burns completely to form CO_2 (carbon dioxide) and H_2O (water). When you adjust the burner to make a blue flame, the burner gets plenty of oxygen mixed with the methane fuel. This causes the methane to burn completely. The chemical equation for the complete burning reaction of methane and oxygen could be stated as follows:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

• 13 –4. In the investigation, what evidence did you have that H_2O was produced when methane burned in plenty of oxygen?

13-4. Small droplets of moisture formed in the test tube.

• 13 –5. In the investigation, what evidence did you have that CO_2 was produced when methane burned in plenty of oxygen?

13-5. Limewater added to the test tube turned slightly milky or cloudy, showing that CO_2 was present.

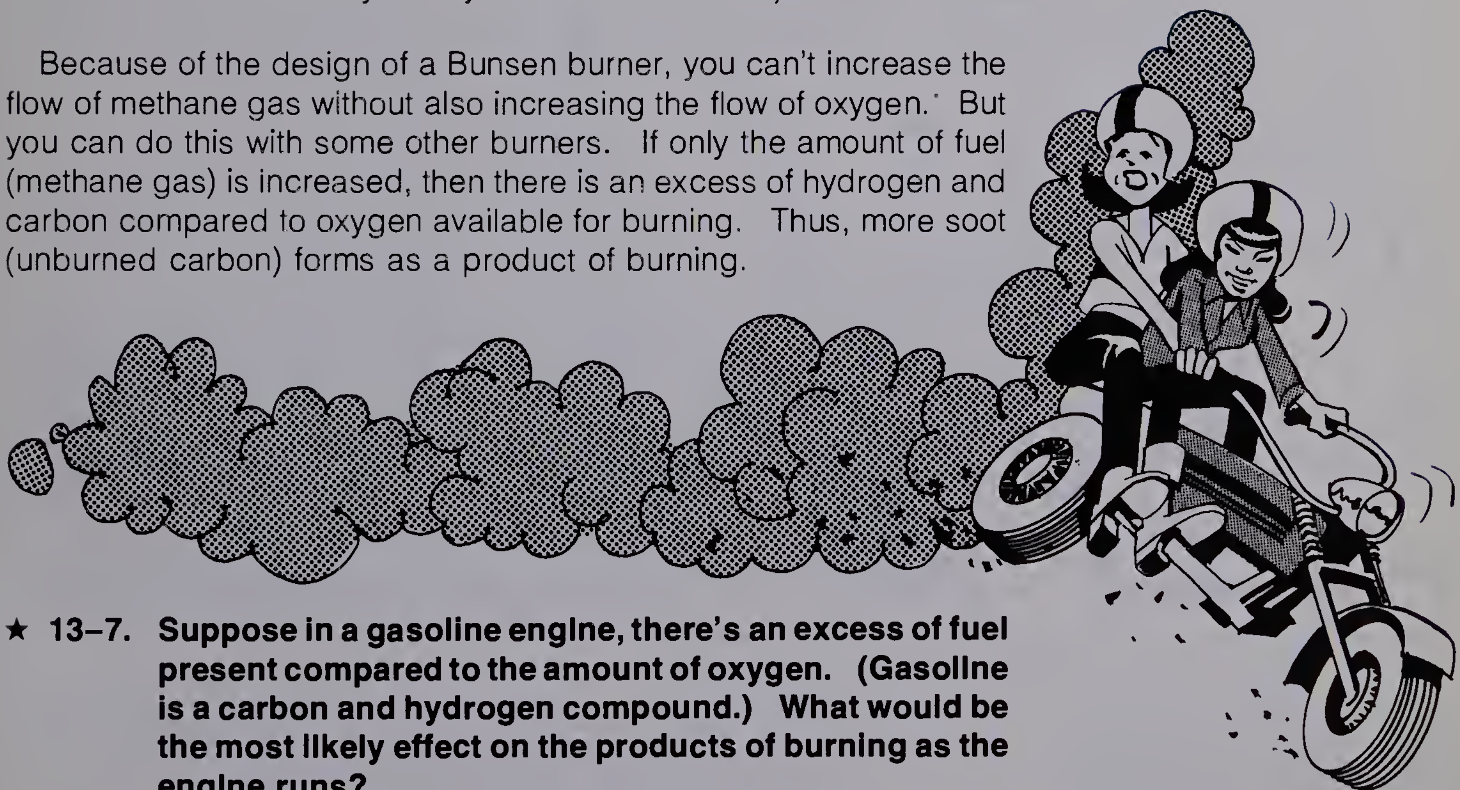
The carbon dioxide gas produced by burning is not usually considered to be a poisonous gas. However, for carbon dioxide to be produced in a fire, some of the oxygen in the air must be used up. If too much oxygen in a room is used up, a person in that room can be asphyxiated.

Other gas products of burning are more dangerous than carbon dioxide. Can these gases be produced when methane burns? Look at the equation for the complete burning of methane and oxygen (page 54). Carbon dioxide and water were produced in that situation. For other gases to be produced, the burning situation would have to be different. The burning situation could be related to the amount of methane or the amount of oxygen or both. So the question is, does changing the amount of methane or the amount of oxygen change the products of metnane burning?

• 13 –6. With a Bunsen burner, how can you change
  a. the amount of methane available for burning? (Hint: Is there a way to adjust the flow of gas?)
  b. the amount of oxygen available for burning? (Hint: Is there a way to adjust the intake of air?)

13-6. (a) Regulate the gas-supply valve; (b) Regulate the air-mix turn sleeve on the burner.

Because of the design of a Bunsen burner, you can't increase the flow of methane gas without also increasing the flow of oxygen. But you can do this with some other burners. If only the amount of fuel (methane gas) is increased, then there is an excess of hydrogen and carbon compared to oxygen available for burning. Thus, more soot (unburned carbon) forms as a product of burning.



★ 13–7. Suppose in a gasoline engine, there's an excess of fuel present compared to the amount of oxygen. (Gasoline is a carbon and hydrogen compound.) What would be the most likely effect on the products of burning as the engine runs?

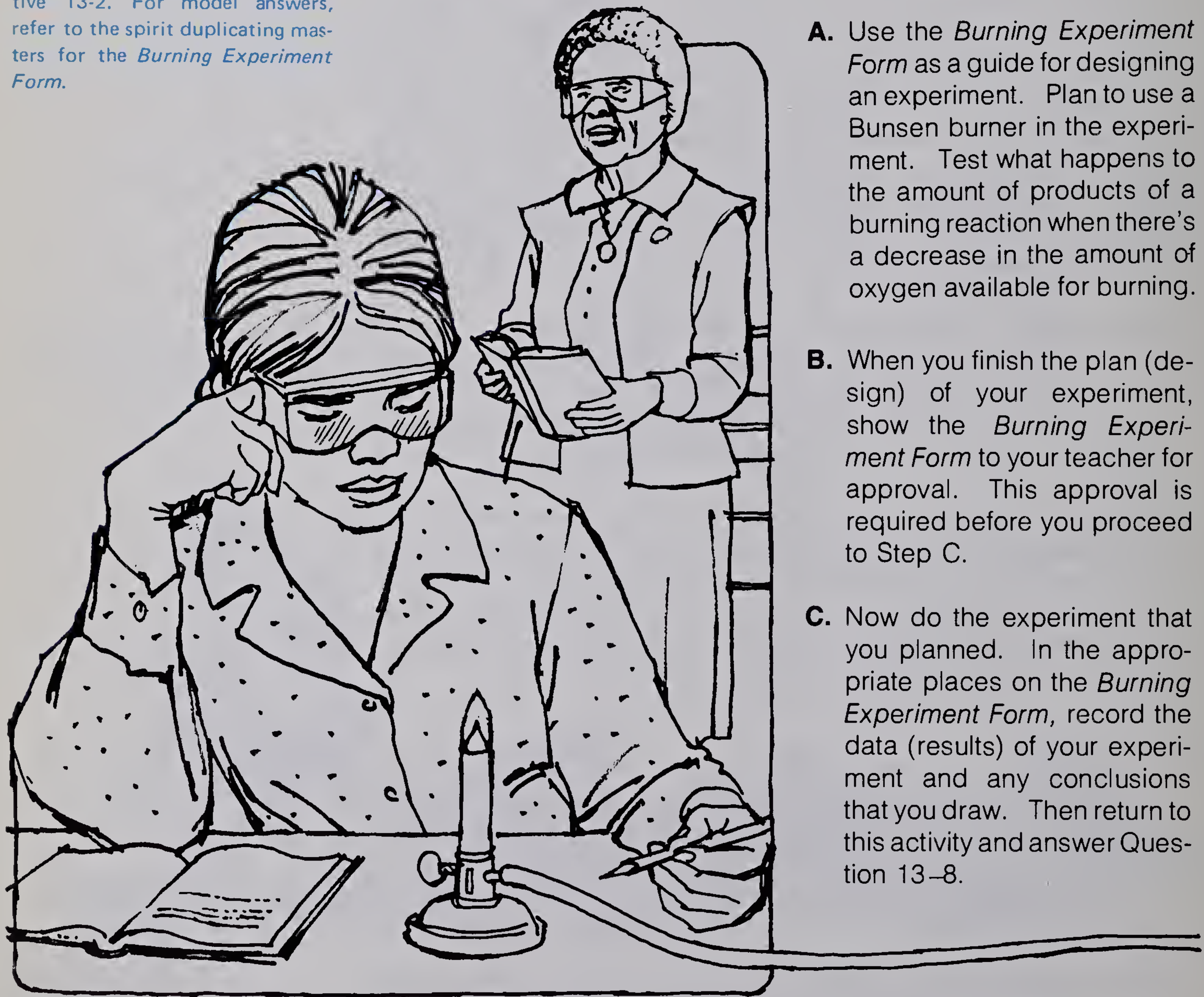
13-7. More soot (solid pollutants) would be produced and would spew out in the exhaust fumes.

You will be asked to check over the students' *Burning Experiment Forms*. Make sure that their experiments are safe to perform. For example, students may want to completely close the air supply to the burner, or to wrap paper around the burner to obstruct the air inlet holes. These are dangerous procedures!

You may want to use the completed *Burning Experiment Forms* as part of your evaluation of each student's performance on Objective 13-2. For model answers, refer to the spirit duplicating masters for the *Burning Experiment Form*.

In this burning reaction, there is a small amount of carbon monoxide produced. Since it is difficult to test for carbon monoxide, students are not required to do so.

The design of a Bunsen burner does allow you to vary the amount of oxygen available for burning. What happens to the products of burning when during a controlled experiment there's a decrease in the amount of oxygen as compared to the amount of methane? Find out by doing the following steps, A through C. If you don't know how to design an experiment, you'll need to do *Resource Unit 15* before you begin Step A. You'll need about 20 minutes and the equipment listed on page 53. You'll also need a copy of the *Burning Experiment Form*, a 2-page form. If you can't find a copy in the classroom, ask your teacher to supply one.



A. Use the *Burning Experiment Form* as a guide for designing an experiment. Plan to use a Bunsen burner in the experiment. Test what happens to the amount of products of a burning reaction when there's a decrease in the amount of oxygen available for burning.

B. When you finish the plan (design) of your experiment, show the *Burning Experiment Form* to your teacher for approval. This approval is required before you proceed to Step C.

C. Now do the experiment that you planned. In the appropriate places on the *Burning Experiment Form*, record the data (results) of your experiment and any conclusions that you draw. Then return to this activity and answer Question 13–8.

13-8. False. A yellow flame and soot are produced due to the reduced amount of oxygen that is available to react with the fuel.

• 13–8. When the amount of available oxygen is decreased during a burning reaction, a blue flame is produced. (True or false.) Explain your answer.

Equations 1 and 2 describe what happens when methane gas is burned.

Equation 1: $2CH_4 + 3O_2 \rightarrow C + CO_2 + 4H_2O$

Equation 2: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

• 13–9. Look at Equations 1 and 2. Which equation better describes the burning of methane gas when not enough oxygen gas is available?

13-9. Equation 1.

Incomplete Combustion

When there is not enough oxygen supplied to burn a fuel completely, partial or incomplete oxidation occurs. This is called *incomplete combustion* and it can be very dangerous. Incomplete combustion puts pollutants, such as sooty carbon, into the air. But worse, incomplete combustion can produce other dangerous substances that lead to asphyxiation. Equation 3 shows another possible chemical reaction for burning methane gas when the supply of oxygen is very limited.

Equation 3: $3CH_4 + 5O_2 \rightarrow 2CO + CO_2 + 6H_2O$

• 13–10. There's a product of burning in Equation 3 that does not appear in Equation 1 or 2. Name the substance.

13-10. Carbon monoxide, CO, gas.

• 13–11. How can the production of poisonous carbon monoxide gas be avoided in a burning reaction?

13-11. Provide good ventilation and plenty of oxygen gas.

★ **13–12. Suppose a fire had burned for a while in a small, closed room. And suppose the fuel for the fire was methane gas. Which of the above equations—1, 2, or 3—would best describe the chemical reaction?**

13-12. Equation 1 or 3.

You probably recognize CO as carbon monoxide, a deadly, poisonous gas. Because carbon monoxide is odorless, colorless, and tasteless, it cannot be easily identified as a product of burning. Carbon monoxide brings on drowsiness and a headache, followed by unconsciousness, and then death. Even small amounts of carbon monoxide may damage brain tissue.

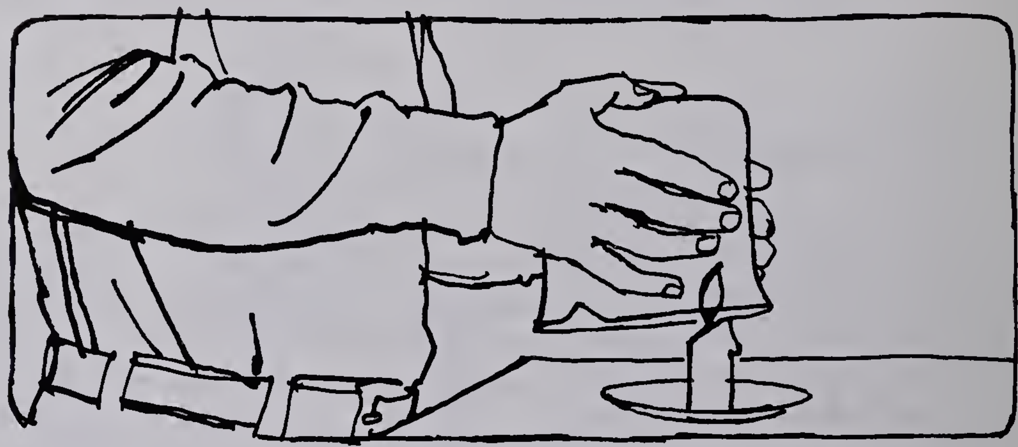
• 13–13. Automobiles do not produce complete combustion of gasoline. Tell why it is dangerous to sit in a car with the motor running in a closed garage.

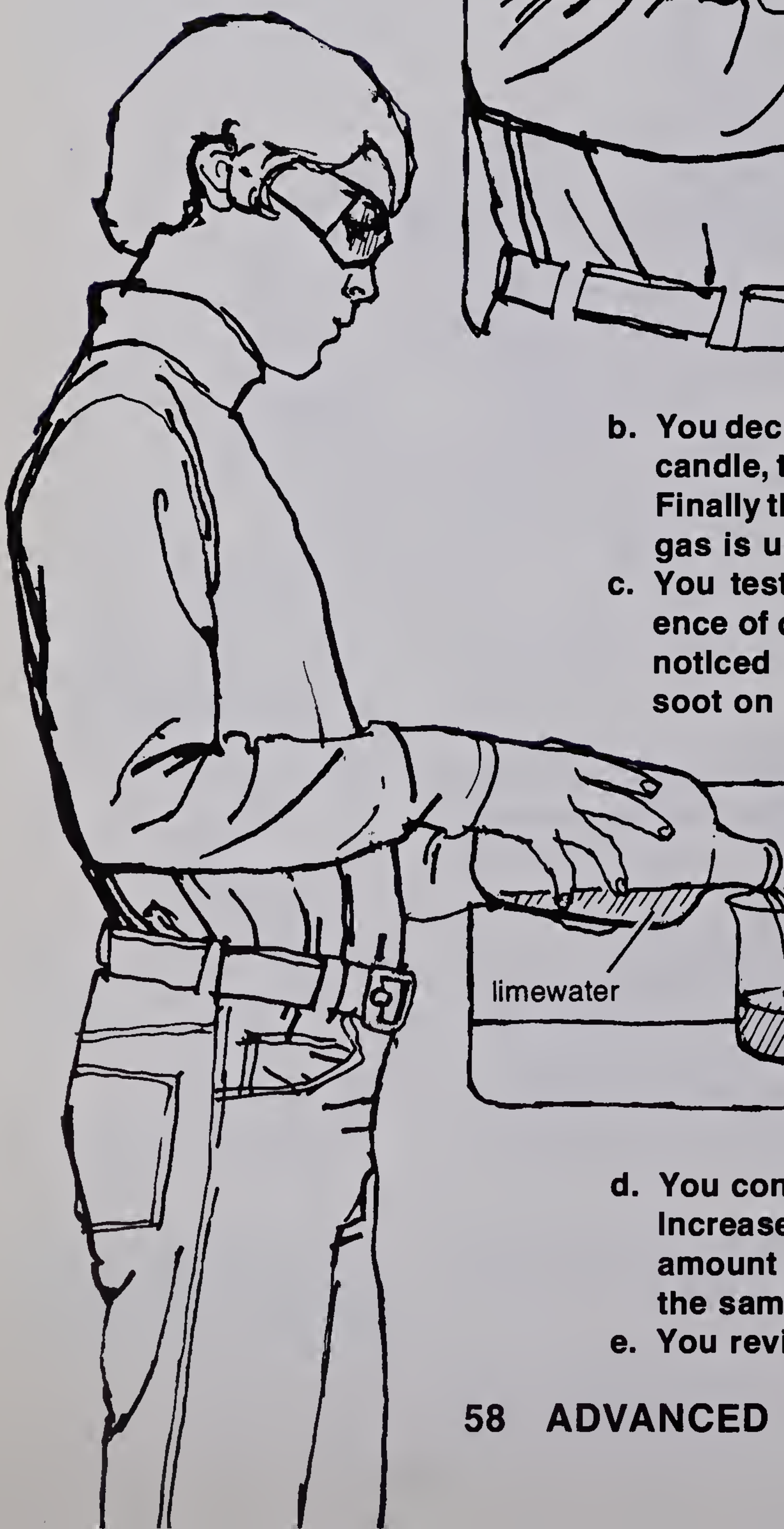
13-13. CO is produced and may leak into the car. This gas is poisonous.

13-14. b, a, c, e, d.

★ 13–14. Procedures a, b, c, d, and e are not in the correct order. When ordered, they describe an experiment designed to test whether decreasing the amount of oxygen has any effect on the amount of various products of the burning reaction. Place the procedures in order.

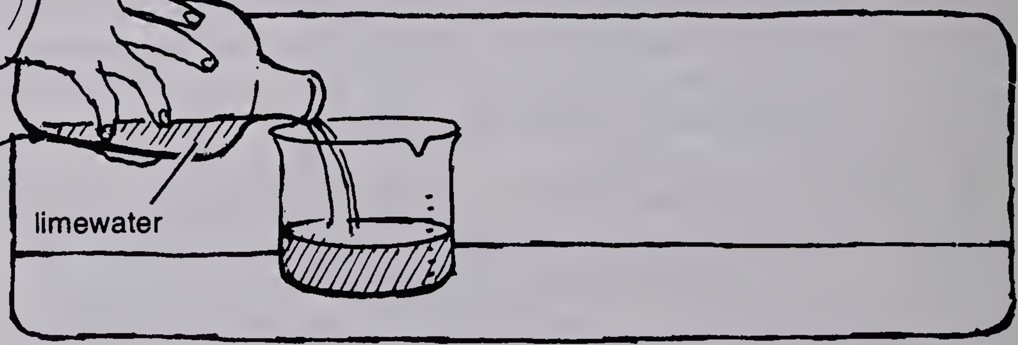
a. You place the beaker over the burning candle. The flame turns yellow and finally goes out. A lot of smoke (soot) is produced in the process.





b. You decide that if you reduce the oxygen supply to a candle, the flame will turn yellow and start to smoke. Finally the flame will go out after much of the oxygen gas is used up.

c. You test the contents of the beaker for the presence of carbon dioxide and water vapor. You have noticed the presence of smoke in the beaker and soot on the walls of the beaker.



d. You conclude that reducing the oxygen supply will increase the amount of soot and smoke, reduce the amount of carbon dioxide gas, and produce about the same amount of water vapor.

e. You review the results of your experiment.

Activity 14
Get Ready, Get Set, Go!

ACTIVITY EMPHASIS: Activation energy in relation to the net energy released in burning; catalysts as agents that reduce activation energy.

MATERIALS PER LAB GROUP
See Materials and Equipment, pp. TM 3-6.
See also Advance Preparation, p. TM 9.

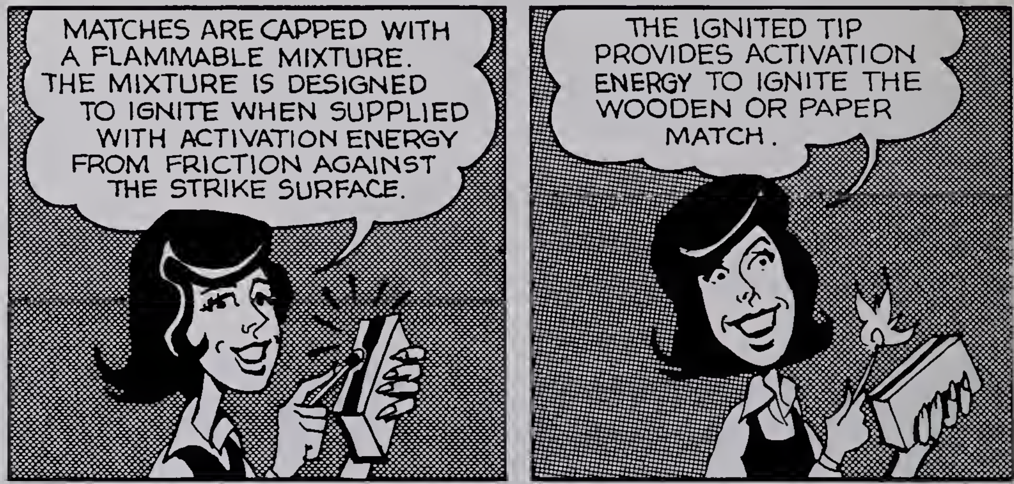
Every chemical change involves energy. In chemical bonds between atoms, ions, and molecules, a form of energy is stored. This energy is called *chemical energy*. When a chemical change occurs, chemical bonds are broken and new bonds are formed as new atom-combinations are produced. Formation of chemical bonds releases energy to the surroundings.

Explosions and flames are dramatic examples of chemical reactions that produce new bonds between atoms, releasing large amounts of chemical energy. In explosions, the energy is released almost all at once; in normal burning, the release is less rapid and more steady.

• 14 –1. In burning reactions, heat energy and light energy are given off. Where does the energy come from?

14-1. From the stored chemical bond energy that's released when chemical bonds are broken and new bonds form.

Before new bonds can be formed, some or all of the bonds for the original atom-combinations must be broken. This takes energy. The energy it takes is called activation energy. *Activation energy* is the energy needed to get a reaction like burning going.

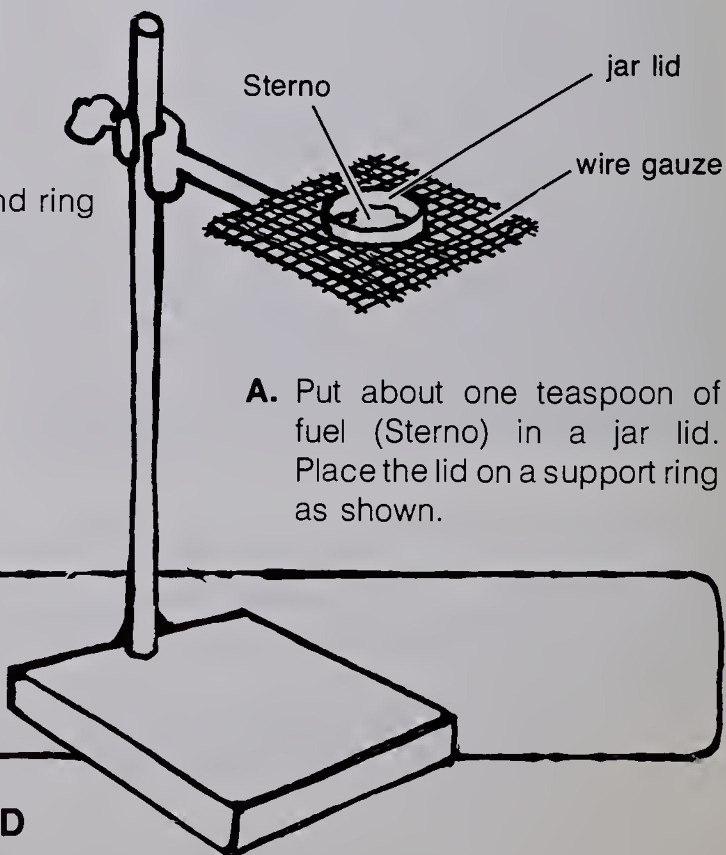


14-2. Activation energy in the form of heat energy.

★ **14–2. What name is given to the energy needed to start combustible and flammable materials burning?**

Have you ever seen a jellylike fuel that's used for cooking? This fuel is used in some stoves for camping or in special pots like fondue pots. In the following investigation, you'll use this fuel to find out more about activation energy. You'll need about 10 minutes and these items:

safety goggles
Sterno
teaspoon
metal jar lid
support stand and ring
wire gauze
Bunsen burner
matches

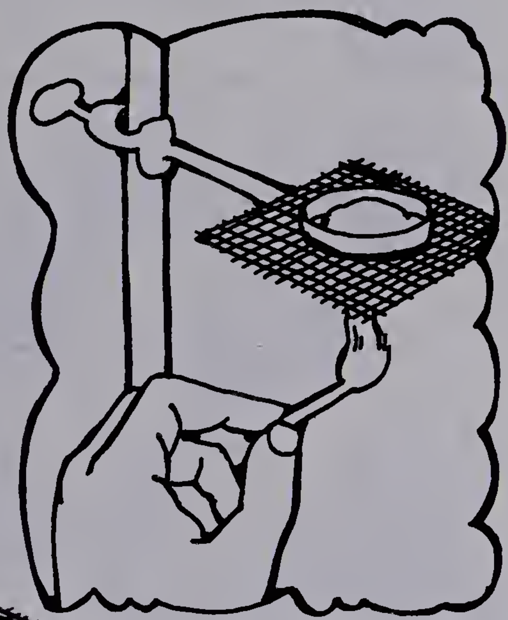


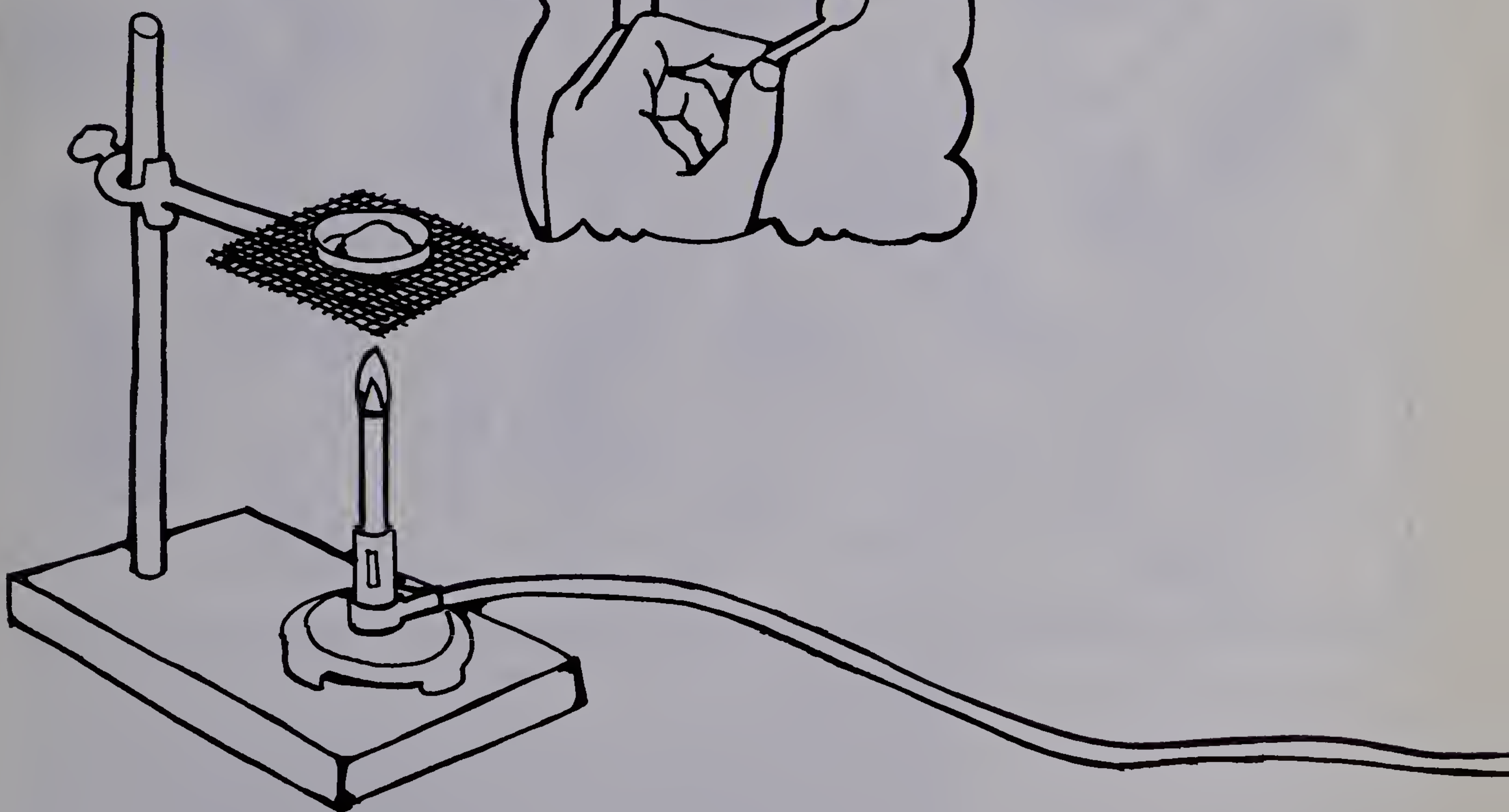
A. Put about one teaspoon of fuel (Sterno) in a jar lid. Place the lid on a support ring as shown.

Most fuels don't ignite unless some energy is supplied to start them burning.

CAUTION **Be careful not to burn yourself. This fuel burns with a pale blue flame that's sometimes difficult to see.**

B. Light a match. Hold the match under the lid and heat the lid. If nothing happens, add a little more energy. That is, light a burner and place it under the lid. When the fuel begins to burn, remove the match (or burner).





• 14–3. What did you add to the fuel to get it to start to react with oxygen?

14-3. Activation energy in the form of heat energy.

• 14–4. Once the fuel was flaming, did *you* have to continue adding heat energy to keep the fuel burning? Explain.

14-4. Not usually. The flame usually supplies enough heat energy to keep the fire going.

The following equation shows a rough description of the reaction of burning fuel.

$$\text{fuel} + O_2 + \text{activation energy} \rightarrow CO_2 + H_2O + \text{heat}$$

The molecules of most fuels have carbon and hydrogen atoms held together by chemical bonds. And in air, the atoms of the oxygen molecules are also held together by chemical bonds. Figure 14–1 shows the chemical bonds for oxygen and *propane,* C_3H_8, a common cooking and torch fuel.

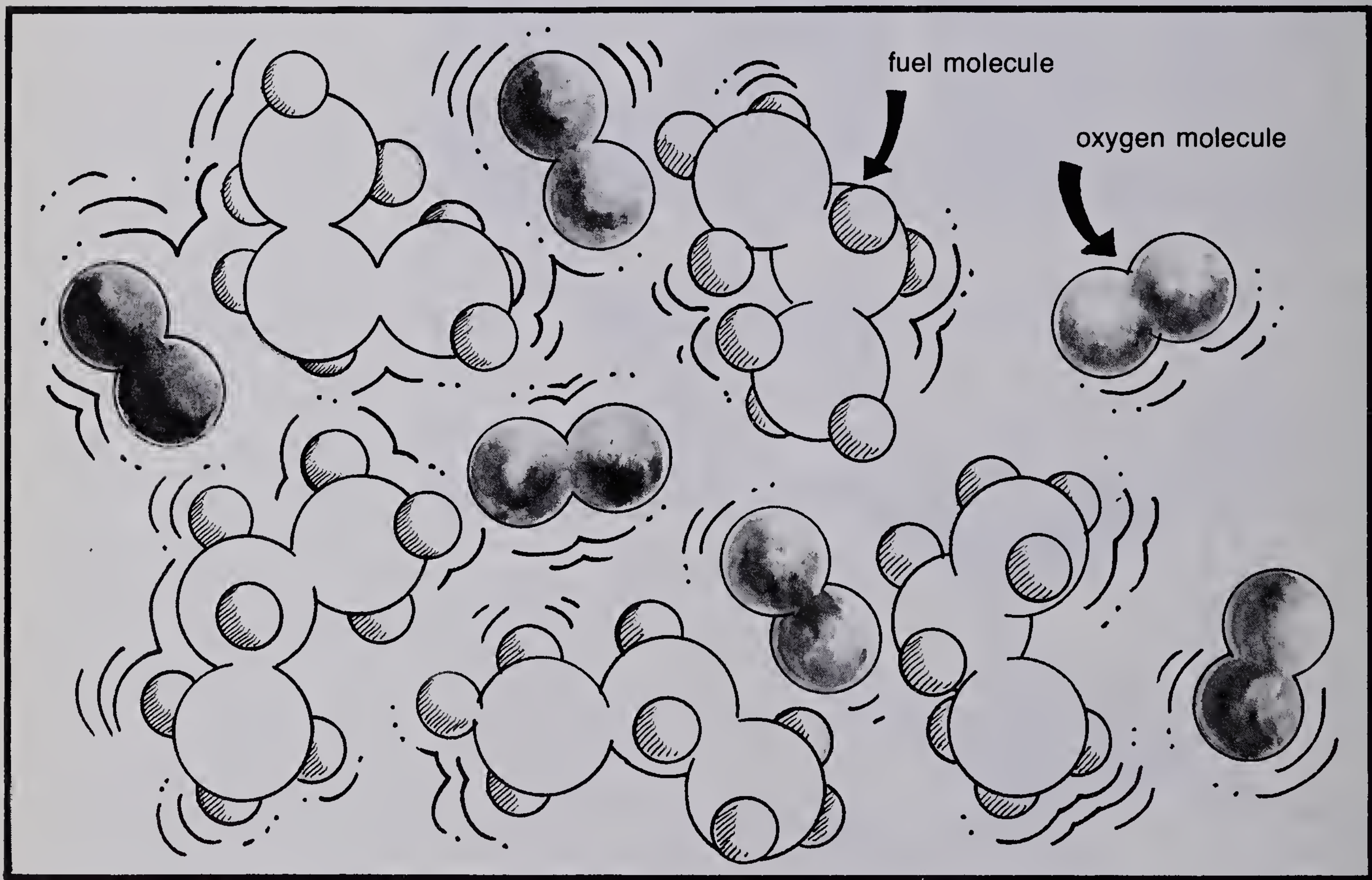


Figure 14–1

When fuel and oxygen molecules are mixed, they will bump into each other, but there won't be much reaction. Reaction occurs only if the molecules have a certain amount of energy when they collide—*activation energy*. For the molecules that have this activation energy, new combinations of oxygen and carbon atoms are formed. Carbon dioxide, CO_2, molecules are produced. And new combinations of hydrogen and oxygen atoms are formed. Water, H_2O, molecules are produced. (See Figure 14–2.)

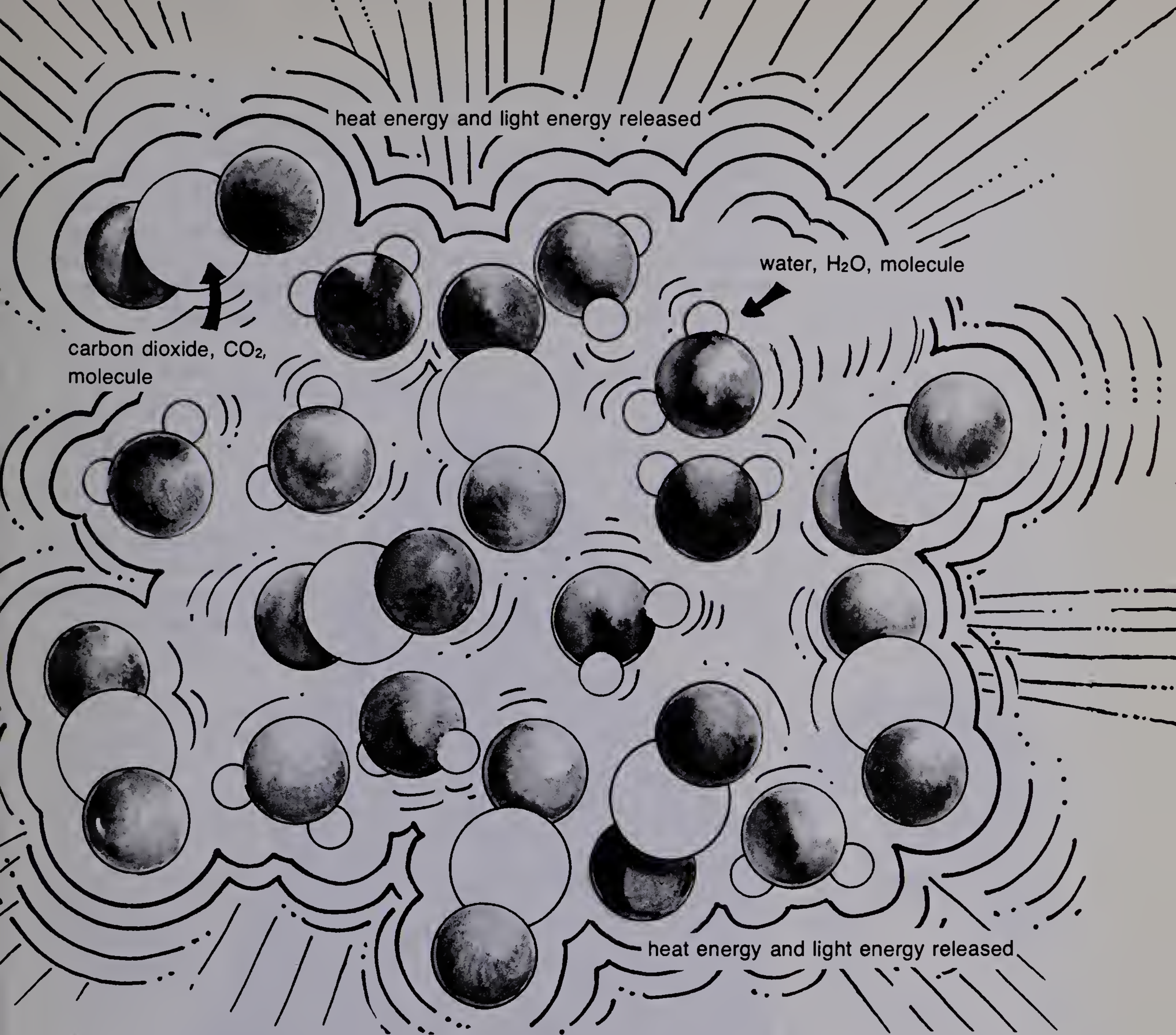


Figure 14–2

When a fuel like propane burns, the bonds between the atoms in the fuel molecules and the bonds in the oxygen molecules must be broken first. In molecules with enough energy—activation energy—the old bonds will break. In the investigation, the Sterno was heated with the match or burner. At higher temperatures, more molecules have the energy needed to begin to react, to break old bonds.

Once the old bonds start to break, new bonds can form. As they form, energy is released in the form of heat and light. The released heat energy is more than enough to keep the temperature raised so that more molecules have enough energy (activation energy) to react. In other words, once started, the reaction keeps itself going.

Now let's look more closely at how all the energy changes relate to each other. Look at Figure 14–3. This diagram shows how energy is involved in the reaction of two molecules (one propane and one oxygen) during the burning of a fuel. The vertical axis represents the amount of energy. The horizontal axis represents the progress of the reaction—from before the fuel is heated to after the products are obtained. The curved line shows the energy changes that take place when a propane molecule and an oxygen molecule react.

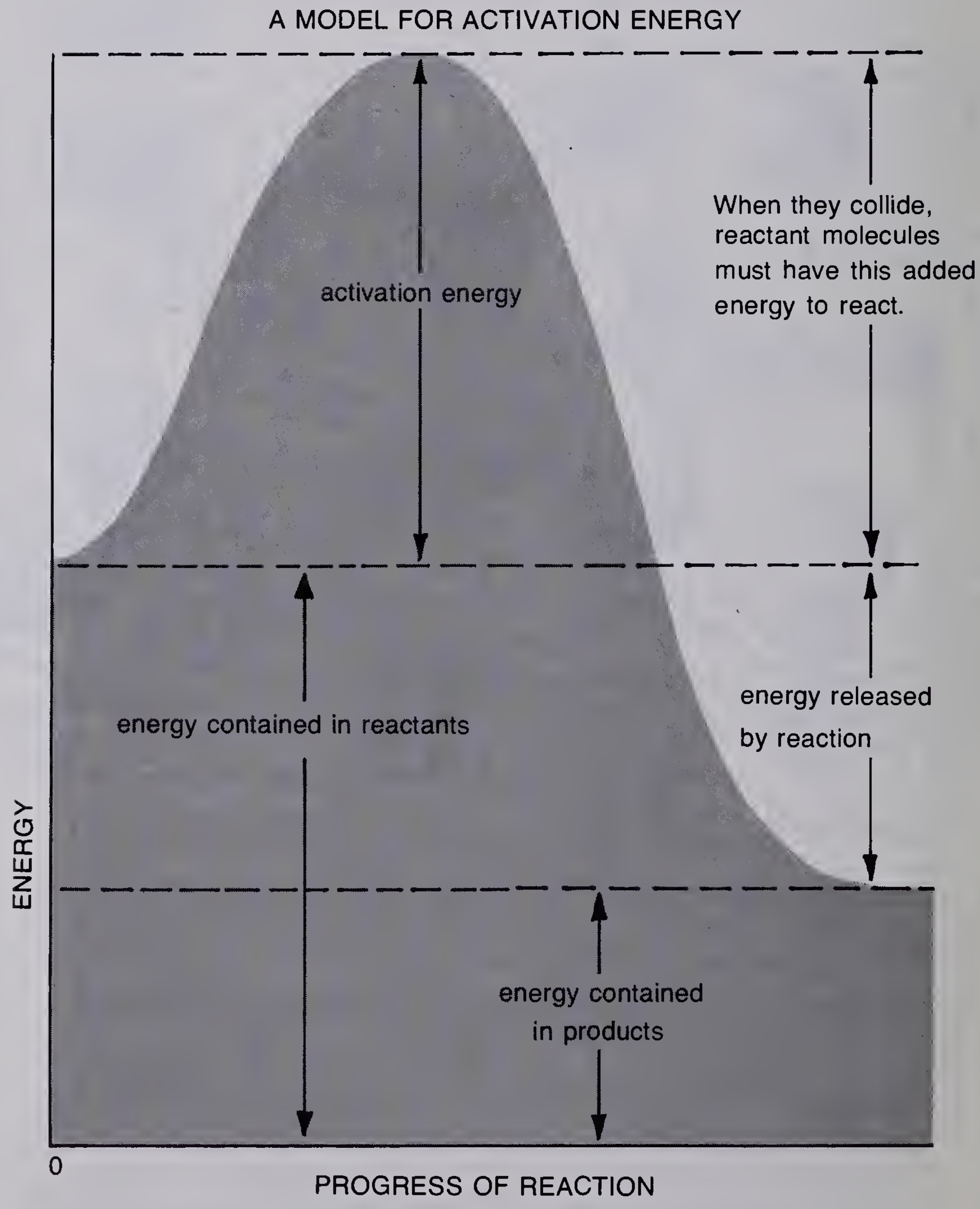


Figure 14–3

Note that in Figure 14–3 the reactants (fuel and oxygen) had a certain amount of energy before the fuel was heated. Then, when the temperature of the reactants was raised (by match or burner), more of the reactant molecules had the energy necessary to react (activation energy) and the fuel ignited. Energy was released as long as burning continued. But new products had been formed.

• 14–5. According to Figure 14–3, what energy must reactant molecules have in order to react?

14-5. Activation energy.

• 14–6. Which have more energy contained in their chemical bonds, the reactants or the products?

14-6. The reactants.

• 14–7. For a burning reaction to continue, the reactants must be at a high enough temperature so that many of the molecules have activation energy. What keeps the reactants at this high temperature?

14-7. The energy released when the new bonds of the product are formed.

★ **14–8. Reactant molecules must have activation energy for a fuel to ignite. Why then does burning continue after ignition?**

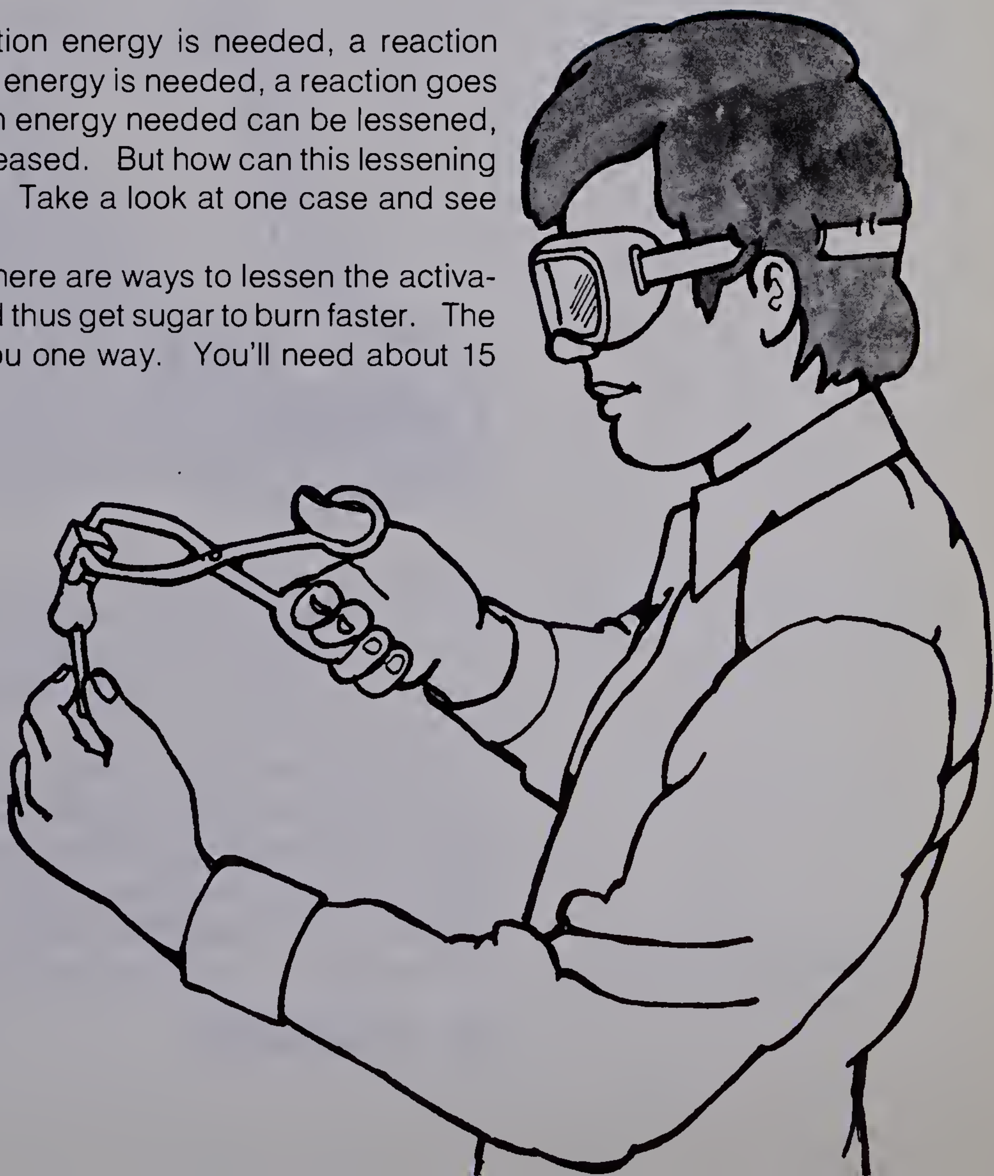
14-8. The energy produced by the reaction is more than enough needed for activation.

When a great amount of activation energy is needed, a reaction goes slowly. When less activation energy is needed, a reaction goes quickly. If the amount of activation energy needed can be lessened, the speed of a reaction can be increased. But how can this lessening of activation energy be achieved? Take a look at one case and see what happens.

Sugar cubes burn slowly. But there are ways to lessen the activation energy needed for burning, and thus get sugar to burn faster. The following investigation will show you one way. You'll need about 15 minutes and the following items:

safety goggles
tongs or test-tube holder
2 sugar cubes
matches
tobacco ash
metal jar lid

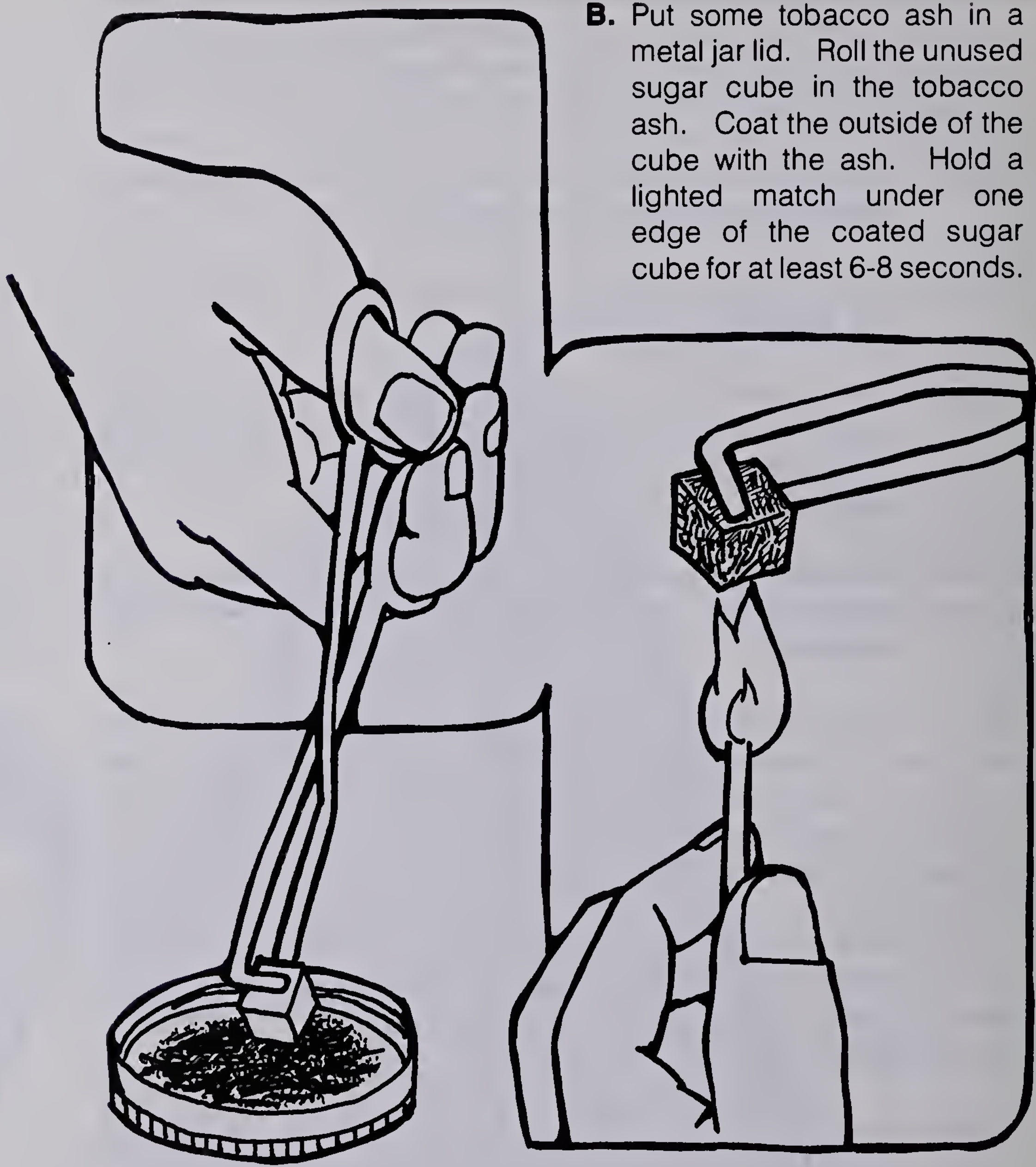
A. Light a match. Using tongs, securely grasp one of the sugar cubes. Hold the lighted match under one edge of the cube for at least 6–8 seconds. Observe what happens.



14-9. It charred slightly.

• 14 –9. Describe what happened to the sugar cube in Step A.

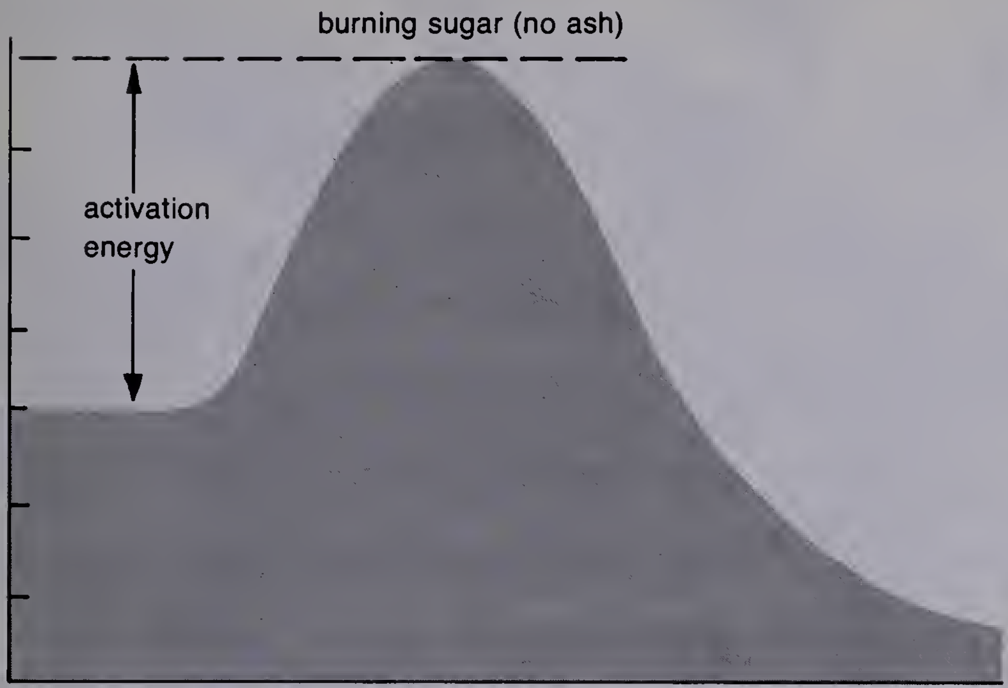
B. Put some tobacco ash in a metal jar lid. Roll the unused sugar cube in the tobacco ash. Coat the outside of the cube with the ash. Hold a lighted match under one edge of the coated sugar cube for at least 6-8 seconds.



14-10. Descriptions may vary. A possible answer is: Faster; more of it burned and the flame was larger.

• 14 –10. Describe what happened to the coated sugar cube. In your description, include any evidence you have that the burning reaction occurred faster, slower, or at the same speed than the reaction for the uncoated cube.

The energy of activation needed to burn sugar must be pretty high because the reaction was slow. But when coated with tobacco ash, the sugar burned much faster. Somehow the tobacco ash lowered the amount of activation energy needed. (See Figure 14–4.) Chemists would say that the tobacco ash acted as a catalyst [CAT-a-list] for the burning reaction.



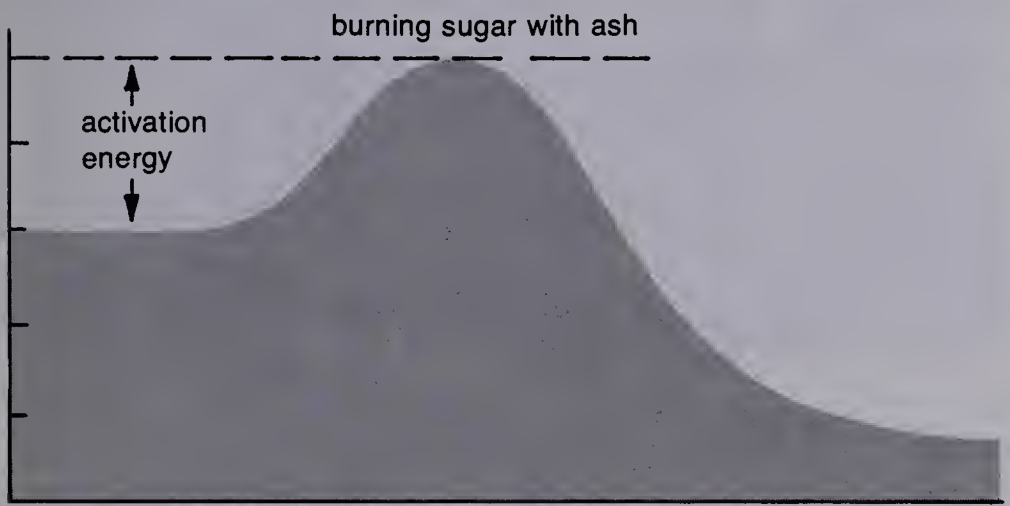


Figure 14–4

Catalysts are substances that are used to reduce the amount of the activation energy needed for a reaction. The exact way in which a catalyst acts to reduce the activation energy is not fully understood.

There are many different catalysts. Some work with some reactions but not with others. Some reactions need a very specific catalyst. Many of the special chemical reactions that occur in your body are catalyzed (caused to occur) by special substances called *enzymes.*

★ **14–11. What effect does a catalyst have on the activation energy of a reaction?**

14-11. It decreases the amount of activation energy needed.

Activity 15 Excursion Planning

Activity 16 Page 69

The Slow Burn

The best way to deal with fires is not to have to deal with them at all. This activity shows you how flammable materials can be made fire resistant.

Activity 17 Page 73

A Watched Pot Boils

Ever boil water in a paper pot? A crazy idea? Well, see for yourself. And while you're at it, see what happens to the temperature of water before and while it's boiling.

Activity 16
The Slow Burn

ACTIVITY EMPHASIS: Some fabrics are flammable and others are not; methods to make flammables more fire resistant. Students treat selected fabrics to make them fire resistant.

MATERIALS PER LAB GROUP
See Materials and Equipment, pp. TM 3-6.
See also Advance Preparation, pp. TM 7, 9, 10.

Other than hair, which burns easily, the human body is not very good fuel for a fire. Unfortunately, many kinds of clothing do make good fuel.

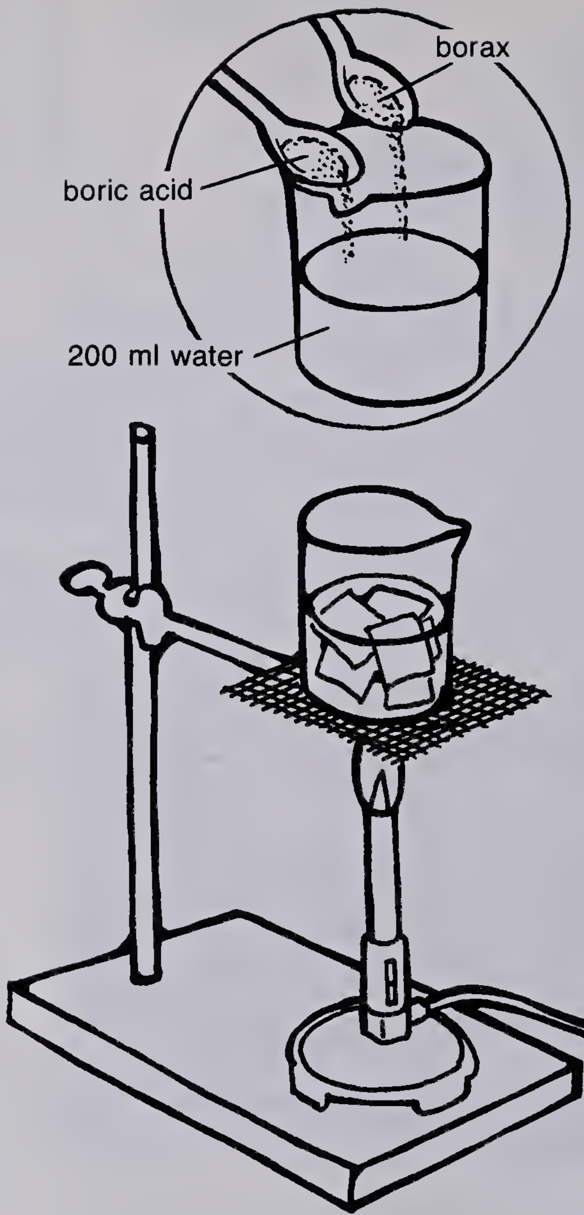
Many materials can be chemically treated to make them much less easy to ignite (catch fire). These materials become fire resistant (flame-retardant clothing, for example). Fire-resistant materials *will* burn, but they won't ignite easily. They are nonflammable. If a material won't ignite *at all*, it is *fireproof*. But scientists have not been very successful in fireproofing flammable fabrics.

• 16–1. Do you think it's important for chemists to continue their research on making fireproof clothing? Why?

16-1. Answers will vary. Most answers probably will be "yes" and "decreasing the chance of human injury" cited as a reason.

To see how cloth can be made fire resistant, do the following two-part investigation. The first part, Steps A–C, will take about 30 minutes to do. The second part, Step D, will take about 20 minutes. You'll need the following items:

safety goggles	Fabric Set
graduated cylinder	wire gauze
water	Bunsen burner
beaker	matches
teaspoon	tongs or tweezers
borax	paper towels
boric acid	notebook
support stand and ring	asbestos pad



A. Pour about 200 ml of water into the beaker. Add about 1 teaspoon (5 g) of borax and 1 teaspoon of boric acid into the water. Stir until the solids dissolve completely.

B. Set up the equipment as shown. Put one piece of each type of fabric in the beaker. Place the beaker on the wire gauze and ring as shown. Light the burner and place it under the beaker. Let the solution boil for 10 minutes.

C. Turn off the burner. Using tongs, remove the fabrics and place them on a paper towel. Blot the fabrics with a second towel. This will speed their drying. You have chemically treated these fabric samples to be fire resistant.

In your notebook, draw a table like the one in Figure 16–1. You'll need the table for recording your observations.

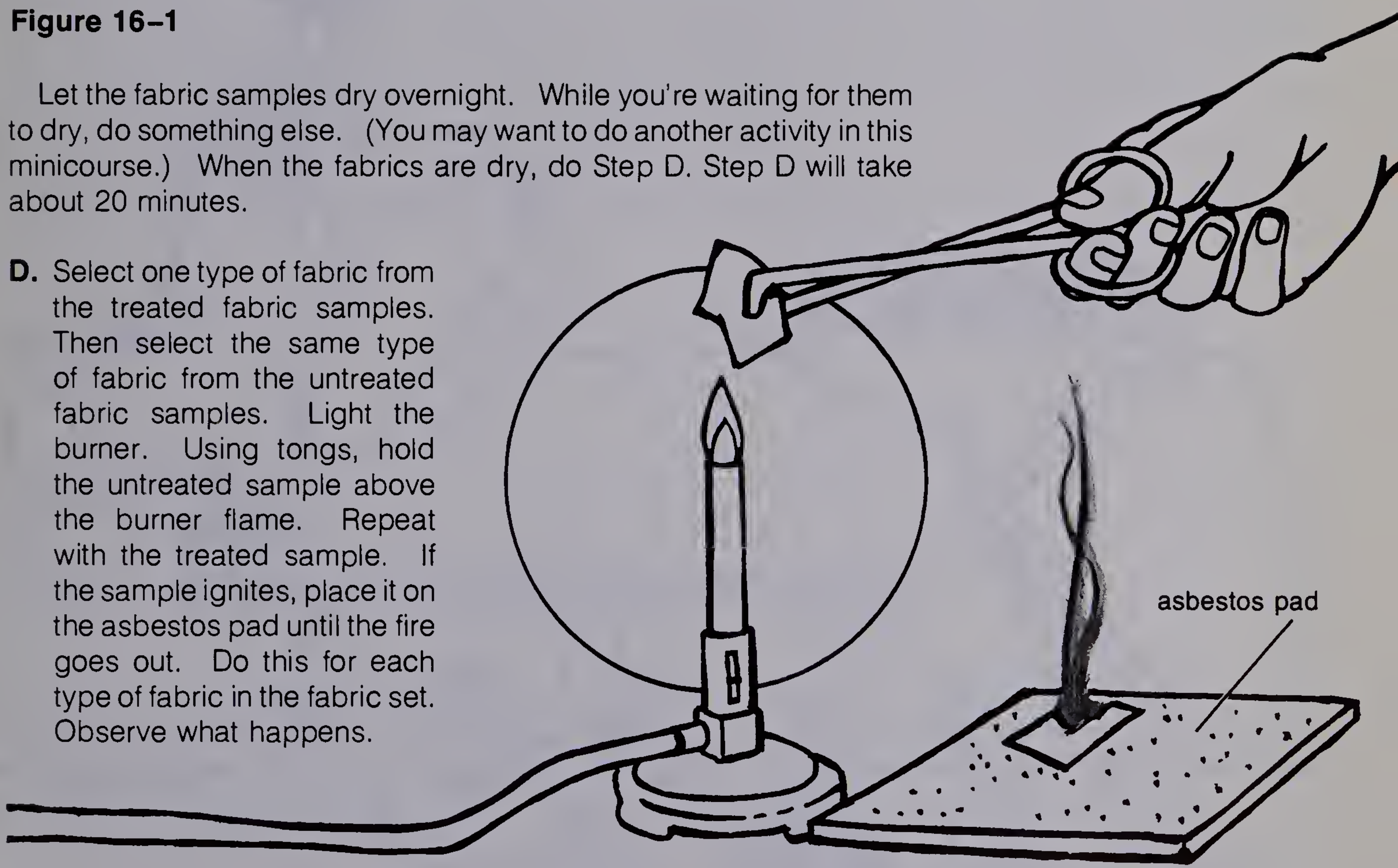
BURNING DIFFERENT MATERIALS

MATERIALS TESTED	UNTREATED SAMPLE	TREATED SAMPLE
1.		
2.		
3.		
4.		
5.		
6.		

Figure 16–1

Let the fabric samples dry overnight. While you're waiting for them to dry, do something else. (You may want to do another activity in this minicourse.) When the fabrics are dry, do Step D. Step D will take about 20 minutes.

D. Select one type of fabric from the treated fabric samples. Then select the same type of fabric from the untreated fabric samples. Light the burner. Using tongs, hold the untreated sample above the burner flame. Repeat with the treated sample. If the sample ignites, place it on the asbestos pad until the fire goes out. Do this for each type of fabric in the fabric set. Observe what happens.



• 16–2. In your notebook, record your observations in the table you drew.

16-2. Answers will vary, but the treated samples should prove to be harder to ignite.

• 16–3. What differences did you observe in how easily the treated and untreated fabrics ignited and burned?

16-3. The treated samples did not burn as easily.

When you treated the fabrics, you did not make them fireproof. You made them nonflammable, or fire resistant. A nonflammable fabric is not easily ignited and doesn't burn rapidly when ignited. But a nonflammable fabric *will* burn if placed in a direct flame.

There are some types of fabrics that don't have to be chemically treated to be nonflammable—they are naturally nonflammable. Wool is one example. However, there are other substances that are *noncombustible*. They won't catch fire—even when placed in a direct flame. Some noncombustible materials will melt, however, or otherwise change in appearance.

16-4. Fireproof materials won't burn at all. But nonflammable materials will burn in a direct flame.

★ 16–4. How does a fireproof material differ from a nonflammable material?

Flame-retardant clothing and household articles are becoming more and more common. The commercial process for making things flame retardant is different from the process you used in the investigation. The commercial process is more complicated and uses chemicals that don't wash out easily. The laundering instructions for flame-retardant articles must be followed carefully.

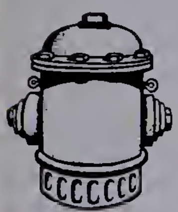
★ 16–5. Why should you follow the manufacturer's instructions for laundering flame-retardant clothes?

16-5. So that you don't make them less flame retardant by washing out the chemicals (used to make them flame retardant).

Many clothes are made flame retardant because state and federal laws require it. After several tragic accidents involving flammable fabrics, Congress passed the Flammable Fabrics Act in 1953 and an amendment to it in 1967. The act makes it illegal for manufacturers to make clothing from highly flammable materials. Also, the act requires children's pajamas and other sleepwear to be made from flame-retardant materials.

There is recent research indicating that certain fire-resistant additives (e.g., TRIS) may cause cancer when added to some clothing. Be aware of the latest information so that you can answer questions relevant to this topic.

Unfortunately, many common items are not flame retardant. These items can burn if they get hot enough. Many plastics burn or melt. Frequently, burning plastic produces poisonous gases. Yet more and more plastics are being used as building materials and for other items in the home.



Activity 17
A Watched Pot Boils

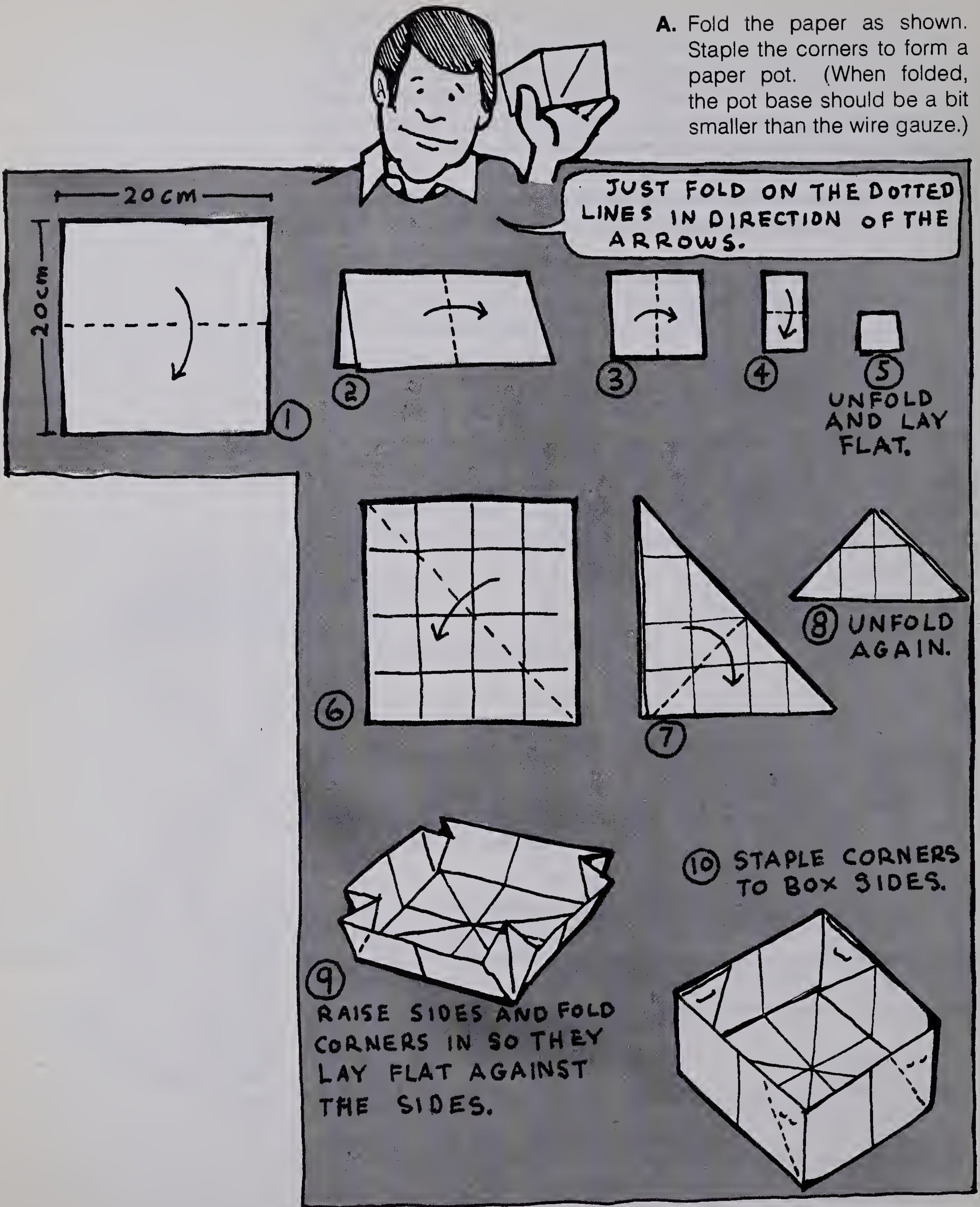
If you put a piece of paper in a flame, the paper will ignite (catch on fire). . If you hold a piece of paper just above the flame, the paper will ignite. What do you think would happen if you tried to boil some water in a paper pot? Would the paper ignite? Find out. Do the following investigation. You'll need about 40 minutes and these items:

ACTIVITY EMPHASIS: Students perform an amazing experiment — boiling water in a paper pot — and the paper won't burn!

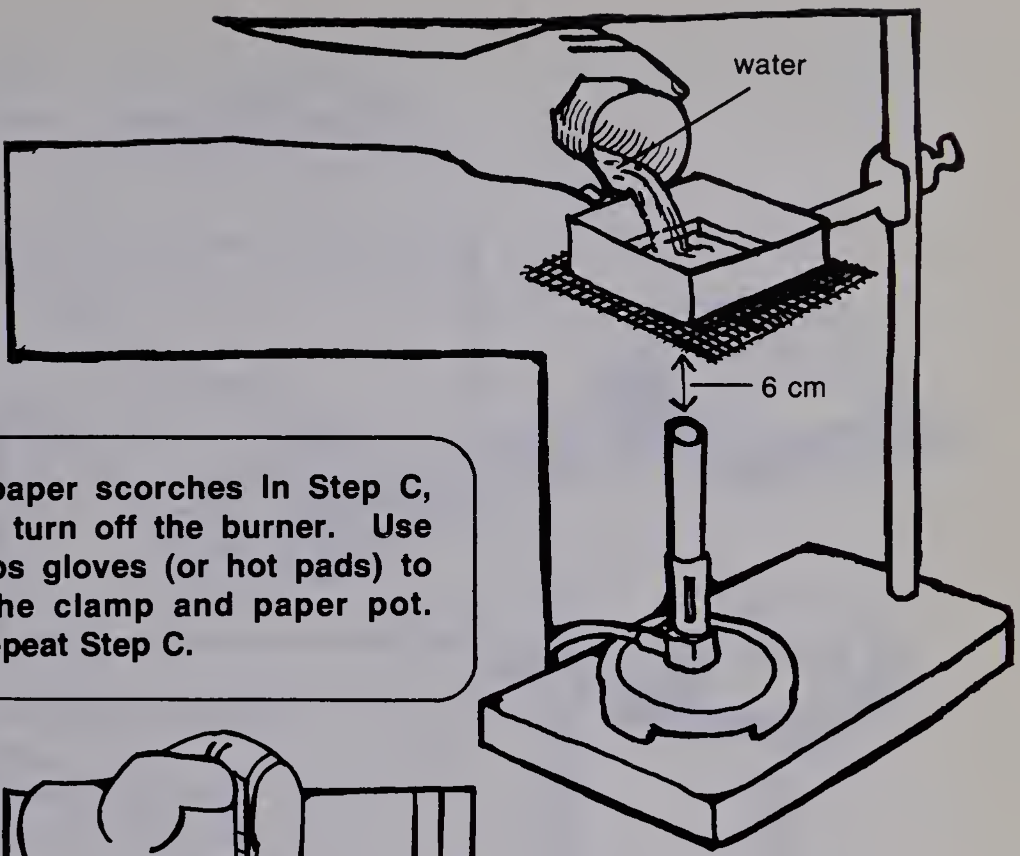
MATERIALS PER LAB GROUP
See Materials and Equipment, pp. TM 3-6.
See also Advance Preparation, pp. TM 10, 11.

- safety goggles
- piece of paper, 20 cm × 20 cm
- stapler
- support stand and ring
- wire gauze
- cup of water
- Bunsen burner
- matches
- asbestos glove or pot holder
- Celsius thermometer
- tongs

A. Fold the paper as shown. Staple the corners to form a paper pot. (When folded, the pot base should be a bit smaller than the wire gauze.)

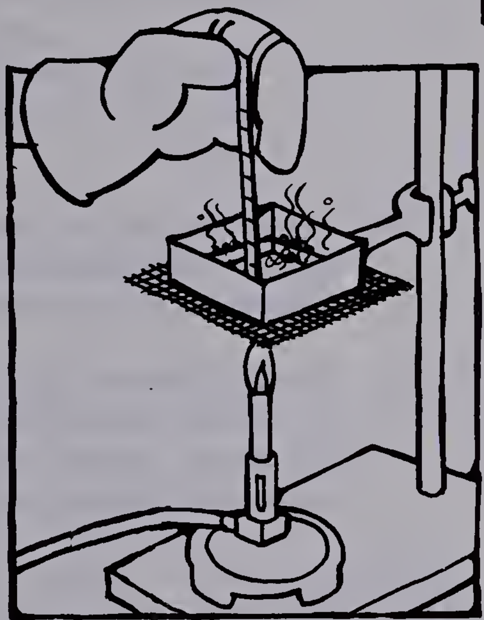


B. Set up the equipment as shown. Place the pot on the wire gauze. Adjust the height of the clamp ring so that the wire gauze is about 6 cm from the top of the burner. Pour enough water into the pot to fill it to a depth of between 1 cm and 2 cm.



CAUTION **If the paper scorches in Step C, quickly turn off the burner. Use asbestos gloves (or hot pads) to raise the clamp and paper pot. Then repeat Step C.**

C. Move the burner away from the equipment, light it, and place it under the wire gauze. Heat the water until it boils. Use asbestos gloves (or a hot pad) to keep the bulb of the thermometer in the water all the time. Read the thermometer about every 30 seconds as the water is heated and while it boils. After the water has boiled for about one minute, turn off the burner.



• 17 –1. What did you observe happening to the water? The paper pot? The temperature?

17-1. The water boiled. The paper pot scorched and had soot on it, but it didn't burn. The temperature rose to about 100° C and stayed there.

• 17 –2. What was the highest temperature that the water reached?

17-2. About 100° C.

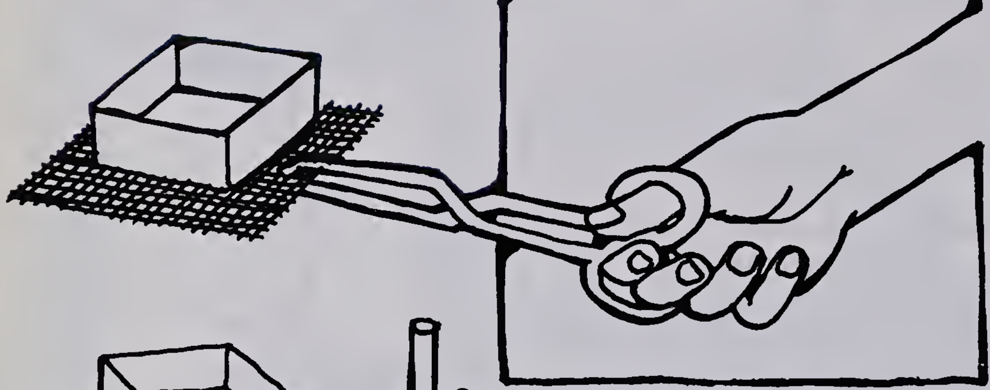
• 17 –3. What do you think the boiling point of water is? (*Boiling point* is the temperature at which something boils.)

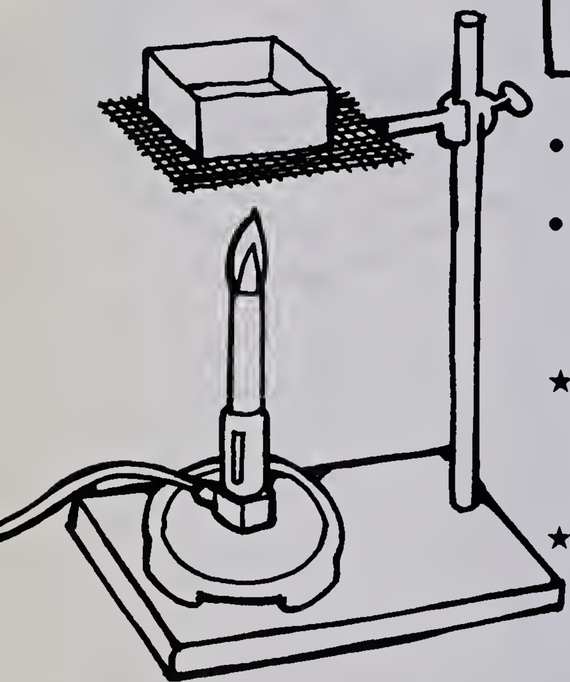
17-3. 100° C.

Why do you suppose the paper pot didn't ignite? Did the water keep it from catching on fire? Or was the paper pot too far from the flame?

17-4. The paper caught fire (if left on the screen for a long enough time).

CAUTION **Before doing Step D, clear the area of excess paper.**





D. Using tongs, lift the wire gauze and paper pot to empty out the water. Use your free hand to keep the paper pot from sliding off the gauze. Put the wire gauze and empty paper pot on the stand. Light the burner and place it under the equipment. Observe what happens.

- 17–4. What did you observe in Step D?

- 17–5. Did about the same amount of heat reach the paper pot in both trials (Step C, page 75, and Step D above)? Explain your answer.

★ **17–6. When the pot and water were heated, the paper didn't ignite. Where did some of the heat go? (Hint: What happened to the temperature of the water?)**

★ **17–7. Once the water started boiling in Step C (page 75), you probably noticed that the temperature remained about the same. About what temperature do you think the paper was when the water started boiling?**

17-5. Yes. The burner was at the same distance from the paper and was supplying the same amount of heat.

17-6. It went into the water, making the temperature of the water rise.

17-7. Probably about the same as the temperature of the water, about 100° C.

The ignition point of ordinary paper is higher than 200°C. But as long as water remains in the paper pot, and the distance from the flame is unchanged, the paper is unlikely to catch fire.

- 17–8. The three basic requirements for a fire are fuel, oxygen (air), and high enough temperature to ignite the fuel. Which requirement was not present in Step C (preventing the paper pot from igniting) but was present in Step D (igniting the pot)? Explain your answer.

17-8. Enough heat to ignite the fuel. In Step C heat is removed as it passes into the water (raising the temperature of the water). Heat is added in Step D since there is no water available to absorb the heat. The heat is enough to ignite the fuel (paper pot).

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William R. Snyder, Associate Director (1974–)
*Robert Vickery, Associate Director (1973–74)

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Betsy Balzano, SUNY, Brockport; David Berey, Roslyn (NY) Schools; Robert Bernoff, Penn. State University; Capt. George Bond, Naval Coastal Systems Laboratory; Ted Bredderman, Delmar, New York; John Cunningham, Keene (NH) State College; James DeRose, Marple-Newtown (PA) School District; Roy A. Gallant, Rangeley, Maine; Orrin Gould, University of Illinois; Francis U. Hackley, Leon (FL) Schools; Jack Hassard, Georgia State University; Robert E. Horvat, SUNY, Buffalo; Stuart J. Inglis, Medford (OR) School District; Jane Kahle, Purdue University; Al Kaskel, Evanston (IL) Schools; David Klasson, Fall River (CA) Joint Unified School District; David Kuhn, Tarrytown (NY) Schools; Clarence T. Lange, Clayton (MO) Schools; Sander Latts, University of Minnesota; Robert L. Lehrman, Roslyn (NY) Schools; Harleen McAda, University of California, Santa Barbara; Wendell Mohling, Shawnee Mission (KS) Schools; Floyd Monaghan, Michigan State University; Rod O'Connor, Texas A & M University; Shirley Richardson, San Diego (CA) Schools; Guenter Schwarz (Deceased); Douglas P. Smith, Florida State University; Claude A. Welch, Macalester College

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